Energy Intensity in the Indian Economy

TEDDY SUPPLEMENT

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Study Team

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Preface

The Tata Energy Research Institute, a non-profit research institute, is engaged in studying, analyzing and finding solutions to the country's energy problems. To facilitate the work of energy policy makers and researchers, TERI brings out annually a comprehensive compilation of energy and related data in the TERI Energy Data Directory and Data Book (TEDDY). Three issues of TEDDY have been published so far.

While TEDDY is basically a compilation of time series data for various energy consuming sectors, the supplement to TEDDY is intended to have a deeper analytical content. In the first issue, the evolution of energy intensities of various energy consuming sectors and sub-sectors is studied in detail. Where possible, both time series estimates and cross-sectional variations have been highlighted and presented. The reasons for the sectoral and sub-sectoral trends in energy intensity are also identified and discussed. Moreover, policy measures and other steps that can be adopted to reduce energy intensities further, have also been pointed out and discussed.

In the coming years, we at TERI plan to study one topic in sufficient depth and publish it as an annual supplement to TEDDY.

R.K. Pachauri
Director
Tata Energy Research Institute

Units

GWh : Gigawatt-hour

kg : kilogram

kgoe : kilogram of oil equivalent

kWh : kilowatt-hour

mcm : million cubic metres

MMT : million tonnes

mtoe : million tonnes of oil equivalent

mtpa : million tonnes per annum

toe : tonne of oil equivalent

Note : 1 kgoe = 10,200 kCal
1 toe = 10.2 million kCal
1 mtoe = 10.2e6 million kCal

I Introduction 1
1.1 Energy Scene 1
1.2 Energy Consumption Intensity 5
1.3 Energy Use and Economic Growth 6

II Agriculture 11
2.1 Introduction 11
2.2 Intensity of Paddy and Wheat Cultivation 13
2.3 Intensity of Pulses, Sugarcane, Oilseeds and Cotton Cultivation 16

III Industry 24
3.1 Introduction 24
3.2 Overall Energy Intensity 24
3.3 Iron and Steel Industry 29
3.4 Cement 31
3.5 Aluminium 33

IV Transport Sector 43
4.1 Introduction 43
4.2 Rail-Road Shift 43
4.3 Energy Efficiency of Rail Transport 45
4.4 The Changing Nature of Road Transport 46
4.5 Energy Efficiency Trends in Shipping 47
4.6 Energy Efficiency Improvements in Air Transport... 49

V Commercial/Services/Government Sector 58
5.1 Introduction 58
5.2 Energy Uses 58
5.3 Trends of Energy Intensity 59

VI Residential Sector 63
6.1 Introduction 63
6.2 Energy Consumption Mix 63
6.3 The Changing Roles of Traditional and Commercial Fuels 65

VII Summary 70

Table 1.1 : Overall Commercial Energy Consumption Intensity of the Indian Economy......... 10
Table 1.2 : Commercial Energy to GDP Elasticity in India................................ 10
Table 2.1 : Energy Intensity for Cultivating Pulses, Sugarcane, Oilseeds and Cotton.......... 18
Table 3.1 : Integrated Iron and Steel Plants........ 37
Table 3.2 : Energy Consumption for Cement Manufacture.................................. 37
Table 3.3 : Energy Intensity of Alumina Production.. 38
Table 3.4 : Energy Consumption per unit of Finished Product in the Aluminium Industry....... 38
Table 4.1 : Energy Intensity of the Railways........ 51
Table 4.2 : Energy Intensity of Road Transport...... 52
Table 5.1 : Energy Consumption in Commercial/Services/Government Sector.................. 61
Table 6.1 : Per-Capita Energy Consumption........... 68
Table 6.2 : Production of Selected Household Appliances................................. 68

Fig 2.1 (a) : Energy Intensity of Paddy Cultivation... 19
Fig 2.1 (b) : Direct Energy Intensity of Paddy Cultivation.................................. 19
Fig 2.2 (a) : Energy Intensity of Wheat Cultivation... 20
Fig 2.2 (b) : Direct Energy Intensity of Wheat Cultivation.................................. 20
Fig 2.3 : Energy Intensity of Paddy Cultivation in Punjab................................. 21
Fig 2.4 : Energy Intensity of Wheat Cultivation in Punjab................................. 21
Fig 2.5 : Energy Intensity of Paddy Cultivation in Nine Major States...................... 22
Fig 2.6 : Energy Intensity of Wheat Cultivation in Nine Major States...................... 22
Fig 2.7 : Energy Intensity of Pulses Cultivation in Eight Major States................... 23
Fig 2.8 : Energy Intensity of Sugarcane Cultivation in Nine Major States.............. 23
Fig 2.9 : Energy Intensity of Oilseeds Cultivation in Nine Major States.................... 23
Fig 2.10 : Energy Intensity of Cotton Cultivation in Nine Major States.................... 23

Fig 3.1 : Energy Intensity of Manufacturing Industry.................................. 39
Fig 3.2 : Energy Intensity of Manufacturing Industry at Two Digit Level of Classification 40
Fig 3.3 : Energy Intensity of Manufacturing Industry at Three Digit Level of Classification................................ 40
Fig 3.4 : Energy Intensity in the Iron and Steel Industry.............................. 41
Fig 3.5 : Energy Intensity in the Cement Industry. 42

Fig 4.1 : Energy Intensity in Transport Sector.... 53
Fig 4.2 : Energy Intensity in the Railways........ 54
Fig 4.3 : Rail Traffic by Steam, Diesel & Electric Locomotion............................. 54
Fig 4.4 : Energy Intensity in Road Transport...... 55
Fig 4.5 : Population of Registered Vehicles....... 55
Fig 4.6 : Occupancy Ratio of Buses............... 56
Fig 4.7 : Average Loading of Trucks.............. 56
Fig 4.8 : Energy Intensity in Water and Air Transport.................................. 57
Fig 4.9 : Revenue Flying Hours of Various Craft... 57

Fig 5.1 : Energy Intensity in the Commecial Sector 62
Fig 5.2 : Energy Consumption in the Commercial/Services/Government Sector............. 62

Fig 6.1 : Consumption of Traditional and Commercial Fuels in Rural Households......... 69
Fig 6.2 : Consumption of Traditional and Commercial Fuels in Urban Households......... 69

I. INTRODUCTION

1.1 Energy Scene

India is a developing economy, striving to take off into "self-sustaining growth". The importance of the energy sector in the process of development can no longer be denied. The development of the energy sector has been an integral part of the overall planning process in India.

Like in other developing countries, a large proportion of the Indian population still depends on traditional energy sources like fuelwood, crop residues and animal wastes. According to one estimate, these fuels account for over 50% of the total final energy consumption. However, it is evident that the relative role of traditional fuels is decreasing, and that they are being increasingly substituted by more efficient commercial fuels. Owing to lack of reliable estimates of the supply and use of traditional energy fuels, the discussion below pertains largely to commercial energy sources.

Total commercial energy supplies in India increased from 92.3 million tonnes of oil equivalent (mtoe) in 1980/81 to about 139 mtoe in 1986/87, registering an average growth rate of over 7% per annum.[1] During the same time period, the increase in indigenous production of commercial energy was from about 72.6 mtoe to over 125 mtoe, at the rate of over 9.5% annum. The share of commercial energy supplies from indigenous sources thus increased from 78.6% in 1980/81 to a little over 90% in 1986/87.

Much of the increased production was in the form of fossil fuels: coal, crude oil and natural gas. Oil and gas production increased largely from the Bombay High offshore basin on the west coast. Crude oil production nearly trebled from about 10.5 million tonnes (MMT) in 1980/81 to nearly 30.5 MMT in 1986/87. Similarly, gross natural gas production more than quadrupled from 2358 million cubic metres (mcm) in 1980/81 to 9853 mcm in 1986/87.

Coal production also increased, from about 114 MMT in 1980/81 to over 179 MMT in 1986/87, as a large number of opencast mines were commissioned, mechanized bord and pillar methods of underground mining were introduced, longwall methods of underground mining were progressively increased, and advanced methods of extracting coal from thick seams were adopted.[2)]

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[1] For detailed commercial energy balances for 1980/81 through 1986/87, refer to the TERI Energy Data Directory and Yearbook (1988). Factors used for converting physical quantities of commercial energy sources to mtoe are : (i) 0.49 mtoe per 1 MMT of coal; (ii) 4000 GWh per 1 mtoe of primary hydro and nuclear electricity; (iii) 1 mtoe of 1 MMT of crude oil; (iv) 1167 mcm per mtoe of natural gas; (v) 1.059 mtoe of 1 MMT for LPG; (vi) 1.029 mtoe per 1 MMT of naphtha and petrol; (vii) 1.020 mtoe of 1 MMT of aviation turbine fuel; (viii) 1.010 mtoe of 1 MMT of kerosene; (ic) 0.956 mtoe of 1 MMT of fuel oils; (x) 1 mtoe of 1 MMT of diesel oils and other refined products; and (xi) 12000 GWh of mtoe of secondary electricity.

After nearly a decade of stagnation, nuclear power development began to make progress in the 1980s, as 2 units of 235 MW each were commissioned at the Madras Atomic Power Project in Kalpakkam near Madras (Tamil Nadu). The development of hydro-electric power slowed down somewhat in the 1980s -- the increase being from 11791 MW at the end of 1980/81 to 15963 MW at the end of 1986/87. In addition to primary hydroelectric and nuclear power generation of about 4.54 mtoe and 0.42 mtoe respectively in 1986/87, about 38 mtoe of coal/lignite, 1.7 mtoe of natural gas and 2.5 mtoe of petroleum products were used for power generation.

India continues to be a net energy importer. Net crude oil and petroleum product imports in 1986/87 were about 16 mtoe. About 1.25 mtoe of superior grade coal were also imported for the iron and steel industry. As a percentage of foreign exchange earnings through commodity exports, India's net oil imports reduced from about 78% in 1980/81 to about 19% in 1986/87. This is due largely to: (i) a rapid increase in indigenous oil production (as mentioned above); and (ii) generally soft oil prices in the international market, particularly after 1986.

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2) A large number of opencast mines are also planned for further expansion; these mines will have higher (than at present) over-burden to coal ratios, annual production capacities, and depth limits. Larger and more powerful equipment will need to be deployed.

Net availability of commercial energy for final consumption increased from about 68 mtoe in 1980/81 to 97 mtoe in 1986/87, at the rate of 6.1% per annum. The industrial sector continues to be the single largest consumer of commercial energy sources, and accounted for 58% of total final consumption in 1986/87. It may be noted however, that this includes the consumption of coking coal and other energy sources (naphtha, fuel oils, natural gas etc.) for non-energy purposes.

The transport sector is also a major energy consuming sector. The share of oil in the total energy consumed in this sector is high; and increased from 71.6% in 1980/81 to 86.7% in 1986/87. This may be explained by the increased diesel locomotion in the railways; as also a steady rise in traffic handled by road transport. In 1986/87, the transport sector accounted for about 45% of the total consumption of petroleum products.

Energy consumed in the agriculture sector almost doubled from 1.59 mtoe in 1980/81 to 2.8 mtoe in 1986/87. Increased mechanization of Indian agriculture -- both for land preparation and lift irrigation -- accounted for this rise. The residential sector accounted for about 11% of the total final consumption of commercial energy in 1986/87, and the commercial/services sector for about 3%.

Traditional energy sources still play a dominant role in the overall energy economy. The sectoral shares of total energy consumption may therefore be considerably different if the role of traditional fuels and draught power is considered.

1.2 Energy Consumption Intensity

Total gross domestic product (GDP) increased from Rs. 824.55 billion (1980/81 prices) in 1970/71 to Rs. 1623.26 billion (1980/81 prices) in 1986/87. This was accompanied by an increase in commercial energy consumption from less than 40 mtoe to about 97 mtoe. During the same time period, commercial energy intensity (defined as the ratio of energy consumed and GDP) rose from 0.047 kgoe/Rs. to 0.06 kgoe/Rs. (Table 1.1).

The relationship between economic productivity and the resulting increase in demand for commercial energy sources may be explained by the gradual substitution of commercial energy for traditional fuels for the same economic activity. An attempt has been made to analyze sectoral energy intensities in the following chapters. For paucity of data, the role of commercial energy sources only has been considered, except perhaps for residential energy uses (where traditional fuels play a very important role).

In chapter 2, findings of two studies on energy consumption in the agriculture sector have been compared; the first study was carried out by the Indian Institute of Management in Ahmedabad (IIMA), and the second by the Tata Energy Research Institute (TERI). Chapter 3 deals with energy intensities in the industry sector, with special reference to three "energy priority" industries -- iron and steel, cement, and aluminium. Chapter 4 focuses on the energy intensity in the transport sector. An in-depth analysis of energy consumption in the rail, road, water and air modes of transport is presented. Chapters 5 and 6 give energy consumption indicators for the commercial/services/Government and residential sectors respectively.

The trends in the variations of the annual average intensity levels are broadly analyzed in chapters 2 through 6; and where possible, the underlying determinants of sectoral energy intensities are highlighted. Before moving on to understanding the factors which underlie the evolution of sectoral energy intensities, it is worthwhile to examine the changing relationship between overall energy use and economic growth.

1.3 Energy Use and Economic Growth

The reasons for year to year changes in the overall average commercial energy consumption intensity may be understood better by comparing the evolution of the commercial energy - GDP elasticity[3]. The energy - GDP elasticity may be defined as the ratio between percentage change in the final consumption of commercial energy over a given time period, and percentage change in GDP during the same time period. In other words, the energy - GDP elasticity is a measure of the impact of a one per cent change in GDP on final commercial energy consumption. As energy prices also have an impact on energy consumption, it may be important to study energy price elasticities (ratio of percentage change in final energy consumption and percentage change in energy prices) as well. However, past experience in India suggests that availability considerations, rather than price levels, have been an important determinant of commercial energy use. It therefore becomes difficult to estimate price elasticities of energy use.

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[3] Unless otherwise specified, the term "energy - GDP elasticity" in section 1.3 will be considered to be synonymous with "commercial energy - GDP elasticity".

Table 1.2 presents estimates of energy - GDP elasticity for the period 1970/71 through 1986/87. Although useful indicators, these estimates may be interpreted with some caution. According to Choe (1978)4), the elasticity estimates may be biased because: (i) the share of traditional fuels in the final energy consumption mix has gradually reduced, which implies that an estimate of the GDP elasticity of commercial energy alone tends to be higher than the true value; and (ii) commercial energy consumption has shifted towards relatively more efficient fuels (for example, from kerosene to LPG for residential cooking in India), which means that an aggregation of fuels based on their intrinsic energy content (rather than "useful" energy content), tends to under-

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4) B.J.Choe, "Energy Demand Prospects in Non-OPEC Developing Countries", Mimeo, The World Bank, Washington, D.C., U.S.A.

(rather than "useful" energy content), tends to underestimate the GDP elasticity. Furthermore, the Indian economy has undergone certain structural changes also since the early 1970s -- which may also explain to a certain extent, the changes in the GDP elasticity of energy use.

Despite such shortcomings, the estimates of energy - GDP elasticity presented in Table 1.2 do provide some useful insights. The estimates show that for every 1% increase in GDP during the 1970/71 to 1973/74 period (i.e. before the first oil price shock), the total commercial energy consumption in the country increased by over 4%. Such high GDP elasticities were typical of several developing countries in the pre-1973 era of low energy prices, when issues like energy economy and conservation were not a major concern. Following 1973/74, the energy - GDP elasticity registered a marked decline to about 1.2 from 1973/74 to 1980/81. This reduction was achieved largely by a reduction in the productivity and output of certain major energy intensive sectors of the economy, as well as due to sharp rises in energy (particularly oil) prices within the country. The overall energy - GDP elasticity during the 1970s was thus about 1.5.

During the 1980s, until 1983/84, our elasticity estimates do not show a significant change from the 1973/74 - 1980/81 levels. This may be due to the fact that the second oil crisis was experienced in 1979/80. However, this was also a period when indigenous oil production was rising rapidly each year, which reduced the oil import bill considerably -- but the compulsions for economic and efficient use of energy remained. Beyond 1983/84 however, when oil prices in the international market became soft and eventually declined, the energy - GDP elasticity increased to about 1.4 between 1983/84 and 1986/87.

Although the energy - GDP elasticity has reduced considerably since the early 1970s, it is still very high compared to that in certain developed economies where it is reported to be less than unity (such as in Japan). While part of the reason for the rather high elasticity levels in India may relate to the fact that its per capita commercial energy consumption levels are still very low, and the use of traditional fuels is still being substituted by commercial energy forms, the inefficient use of energy in a variety of end-use applications cannot be ignored.

Table 1.1: Overall Commercial Energy Consumption Intensity of the Indian Economy

	Commercial Energy Consumption (mtoe)	GDP (Rs billion, 1980/81 prices)	Intensity (kgoe/Rs)
1970/71	39.3	824.5	0.0477
1975/76	51.8	940.4	0.0551
1980/81	68.2	1222.3	0.0558
1981/82	74.1	1297.8	0.0571
1982/83	79.7	1338.3	0.0596
1983/84	83.1	1443.9	0.0576
1984/85	85.9	1489.6	0.0577
1985/86	92.7	1560.8	0.0594
1986/87	97.4	1623.3	0.0600

Table 1.2: Commercial Energy to GDP Elasticity in India

1970/71 to 1973/74	4.320
1973/74 to 1980/81	1.196
1970/71 to 1980/81	1.525
1980/81 to 1983/84	1.204
1983/84 to 1986/87	1.387
1980/81 to 1986/87	1.305

II. AGRICULTURE

2.1 Introduction

Agriculture productivity depends upon several factors including the area of land under cultivation, type of soil, extent of multiple cropping, the choice of crop, use of high yielding varieties, use of organic and inorganic fertilizers, the coverage of surface and ground-water irrigation schemes, the extent of mechanization for land preparation, and so forth.

Direct commercial energy input in agriculture is largely for two activities -- mechanized land preparation, and mechanized lift irrigation -- although commercial energy is also required for harvesting, threshing, drying and winnowing. As discussed in TEDDY 1988, the data base on direct commercial energy consumption in agriculture is rather weak, except perhaps for electricity use for irrigation pumping.

However, as the use of commercial energy usually substitutes some form of human and/or animal energy, it is not possible to correlate direct commercial energy input with productivity or value added. This observation is validated further by noting that reliable irrigation facilities (say electric/diesel pumpsets) may influence agricultural output in three ways: (i) by encouraging the use of high yielding varieties and inorganic fertilizers; (ii) by increasing the gross cropped area by making double/multiple cropping possible; and (iii) by bringing about a change in the cropping patterns.

It is therefore necessary to include not only indirect energy consumption (through inorganic and organic fertilizers pesticides etc.) but also human and animal power input, in order to assess the energy intensity of agricultural productivity. This highlights several other data-base deficiencies. First, the amount of useful work done by expending human and animal muscle power is difficult to quantify. And second, in general, apart from data gathered from sample surveys, the use of various types of fertilizers for cultivating various crops is not known. It is therefore difficult to estimate the energy intensity, although an attempt is made below. As paddy and wheat are two major crops, and accounted for about 64% of the irrigated area under cultivation in 1982/83, energy intensities of cultivating these two crops are discussed at length in section 2.2 below. Energy intensities of four other crops (pulses, sugarcane, oilseeds and cotton) are also discussed in section 2.3. Along with paddy and wheat, these four crops accounted for over 64% of total cropped area in 1982/83.

It is known that all crops are cultivated in various types of farms, ranging from traditional (employing human labour or/and bullocks) to modern (with tractors and mechanized pumps, harvesters, threshers and so forth). Any study which estimates the energy intensity of agricultural activity must recognize the importance of distinguishing between the various cultivation techniques. Likewise, it is also important to take into account the use of direct and indirect sources of energy.

A research study by the Indian Council of Agricultural Research (ICAR), entitled "Research Digest on Energy Requirements in Agricultural Sector (1971/1982)" has attempted to account for such heterogeneities in crop cultivation. In particular, farms are classified on the basis of type of farm power used: (i) bullock farms -- which employ bullock power supplemented by human labour; (ii) tractor farms -- which have tractors as the main source of power supplemented by human labour; and (iii) power tiller farms -- which have power tillers as the main source of power, and human labour is used to drive the power tillers and carry out other operations. Farms have also been classified on the basis of operational area as: (i) marginal, with cultivable area of less than one hectare; (ii) small, with area of between one and two hectares; (iii) medium, of area from two to four hectares; and (iv) large, with an area of over four hectares.

2.2 Intensity of Paddy and Wheat Cultivation

Intensity estimates (in kgoe/kg of crop yield) presented below are based primarily on two interesting projects concluded in 1988. The studies were done by the Tata Energy Research Institute (TERI) and the Indian Institute of Management, Ahmedabad (IIMA) respectively. Both were sponsored by the Advisory Board of Energy, Government of India.

Owing to the problems discussed in section 2.1, it is not surprising that the two studies came up with substantially different estimates of intensities (refer to Figures 2.1, 2.2, 2.3 and 2.4; Figures 2.1 and 2.2 are based on findings of the TERI study, while Figures 2.3 and 2.4 are based on the IIMA study). In fact, the differences may also be, at least in part, to the different methodologies adopted. While the TERI study relied almost exclusively on field survey data gathered for several states, the IIMA study used mostly secondary level information. Field survey data were available only for Punjab and Bihar, on the basis of which, energy consumption for cultivating the six major crops was estimated at the all India level.

The two studies differed also, in that: (i) the estimates of energy inputs (human, animal, commercial energy and indirect sources) were made for various farm size categories within a reasonably homogenous agroclimatic zone in a given state, in the TERI study; and (ii) the estimates of energy inputs (excluding human and animal power) were made for farms employing traditional, transitional and modern agricultural techniques in a given state, in the IIMA study. It is evident that there was little effort to understand the differences in energy inputs on the basis of level of farm mechanization in the TERI study; and in the IIMA study, little was done to understand the variations in energy inputs that can arise from various agroclimatic conditions within a state, and due to different sizes of land-holdings within an agroclimatic zone.

As the IIMA study has not considered the contributions of animal and human power inputs in the cultivation activity, a direct comparison of the two studies is possible only if their contributions are excluded. As may be anticipated on the basis of the discussions above, the results obtained from the two studies are very different. For instance, for paddy cultivation, the intensities are estimated to be: 0.7755 kgoe/kg in Punjab in the IIMA study, and 0.16078 kgoe/kg in Central Plains and 0.23467 kgoe/kg in the Western plains of Punjab in the TERI study. Likewise, for wheat cultivation, the corresponding intensities are 0.12056, 0.28049 and 0.31489 kgoe/kg respectively. It may be noted that according to the TERI study, the overall intensity for wheat cultivation is higher than that for paddy, while the reverse is observed from the IIMA study.

For comparative purposes alone, energy consumption intensities for paddy and wheat for nine major states (including Punjab) are derived from data in the IIMA study and presented in Figures 2.5 and 2.6 respectively. It is interesting to note the range of energy intensities observed: for paddy, from 0.00868 kgoe/kg on traditional farms in Madhya Pradesh to 0.36565 kgoe/kg on modern farms in Tamil Nadu. Likewise, for wheat, the range is from 0.00774 kgoe/kg on traditional farms to 0.47683 kgoe/kg on modern farms, both in Rajasthan. The energy intensities vary from one state to another because of differences in agro-climatic conditions and agricultural practices. The differences may also be because the basis for classifying farms into traditional, transitional and modern ones (which essentially depends on the actual fertilizer doze as percentage of the recommended doze, and seed varieties in use) may not be adequate. In actual practice, the level of mechanization (say for land preparation) may vary substantially even in a particular fertilizer use category.

2.3 Intensity of Pulses, Sugarcane, Oilseeds and Cotton Cultivation

Figures 2.7 through 2.10 present estimates for direct commercial energy use plus indirect use of energy per kg of yield of the following four crops respectively: pulses, sugarcane, oilseeds and cotton. Information in Figures 2.7 through 2.10 are based on the findings of the IIMA study. The ranges of intensities observed are again rather wide. These four crops accounted for 25.6% of gross cropped area in 1981/82. Table 2.1 gives data for the states which have the maximum and minimum energy intensity of cultivating each of the crops on farms using "modern" methods, as well as estimated all-India average intensities.

It may be noted from Table 2.1 that for three of the four crops considered, the minimum energy intensity is experienced in West Bengal. Although the variations in intensities may be due in part to differences in agro-climatic conditions, they may also reflect the fact that the role of human and animal power have been neglected. However, as mentioned in section 2.2 above, the energy inputs from these two sources is not considered in the IIMA study.

Table 2.1 : Energy Intensity for Cultivating Pulses, Sugarcane, Oilseeds and Cotton (kgoe/kg)

	Traditional Farms	Transitional Farms	Modern Farms	All Farms
Pulses				
- Rajasthan	0.00211	0.07130	0.76250	0.00493
- West Bengal	0.00023	0.03213	0.04011	0.00469
- All India	0.00070	0.12220	0.09968	0.01032
Sugarcane				
- Gujarat	0.00141	0.00633	0.45713	0.01689
- West Bengal	0.00094	0.00235	0.01501	0.00305
- All India	0.00117	0.00399	0.03471	0.00657
Oilseeds				
- Gujarat	0.00493	0.03987	0.97664	0.08490
- Kerala	0.01055	0.03073	0.10484	0.01712
- All India	0.00868	0.03659	0.48316	0.04925
Cotton				
- Maharashtra	0.20499	0.75945	11.05545	0.43883
- West Bengal	0.05817	0.12501	0.23220	0.13955
- All India	0.23290	0.59082	1.62539	0.70926

Source : Estimates based on data in IIMA, "Energy Demand for Agriculture in India in the Year 2000", Ahmedabad, April 1988.

FIG. 2.1(a) ENERGY INTENSITY OF PADDY CULTIVATION

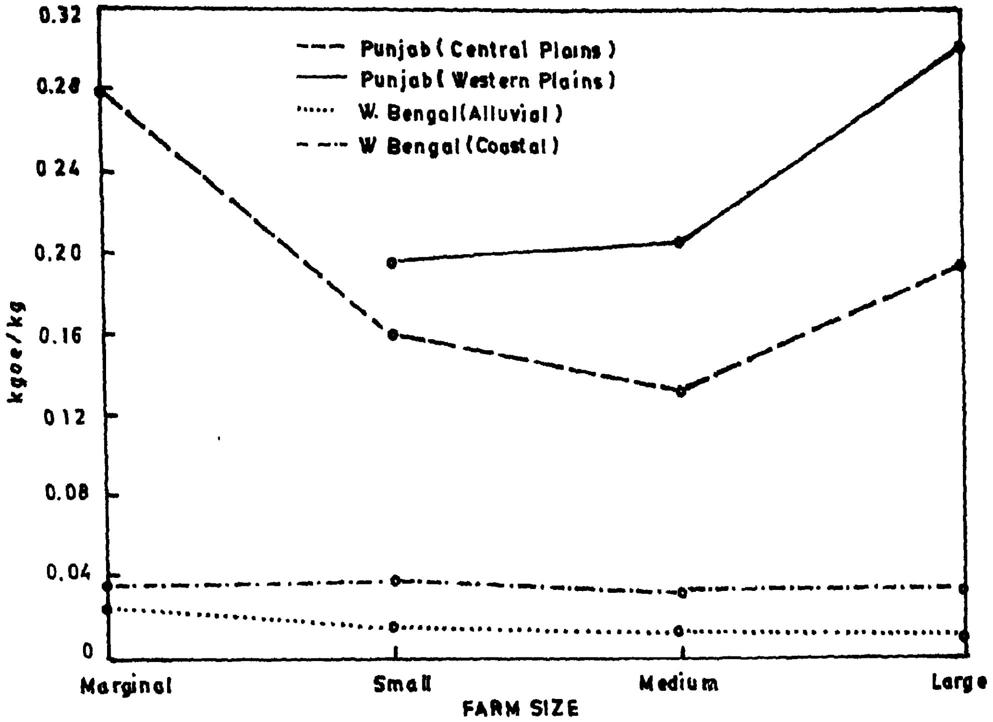


FIG 2.1(b) DIRECT ENERGY INTENSITY OF PADDY CULTIVATION

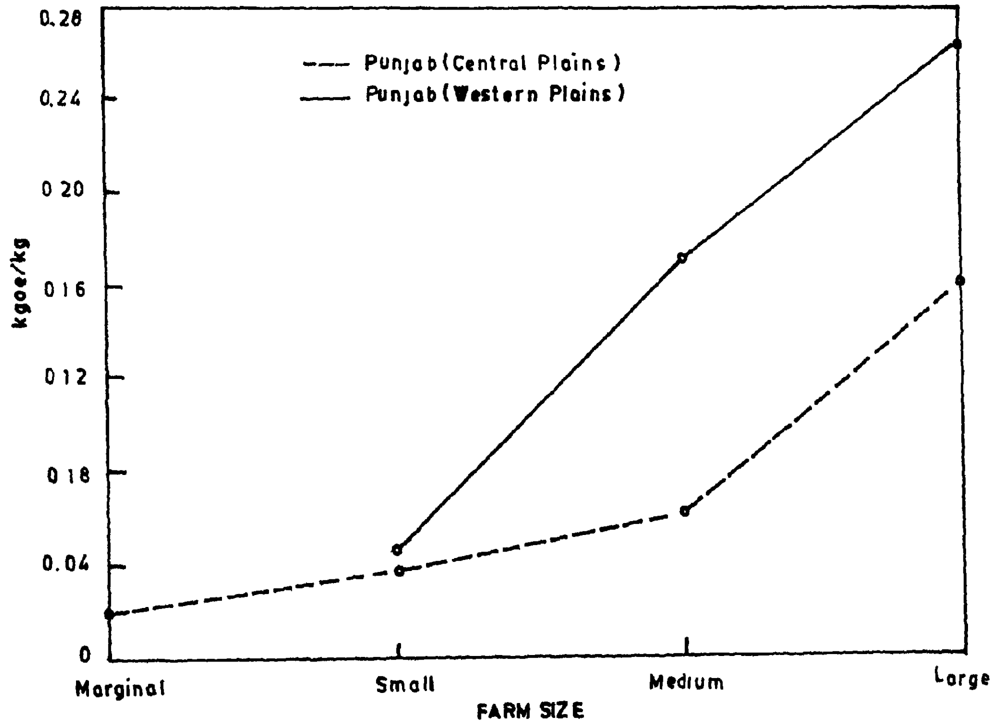


FIG. 2.2(a) ENERGY INTENSITY OF WHEAT CULTIVATION

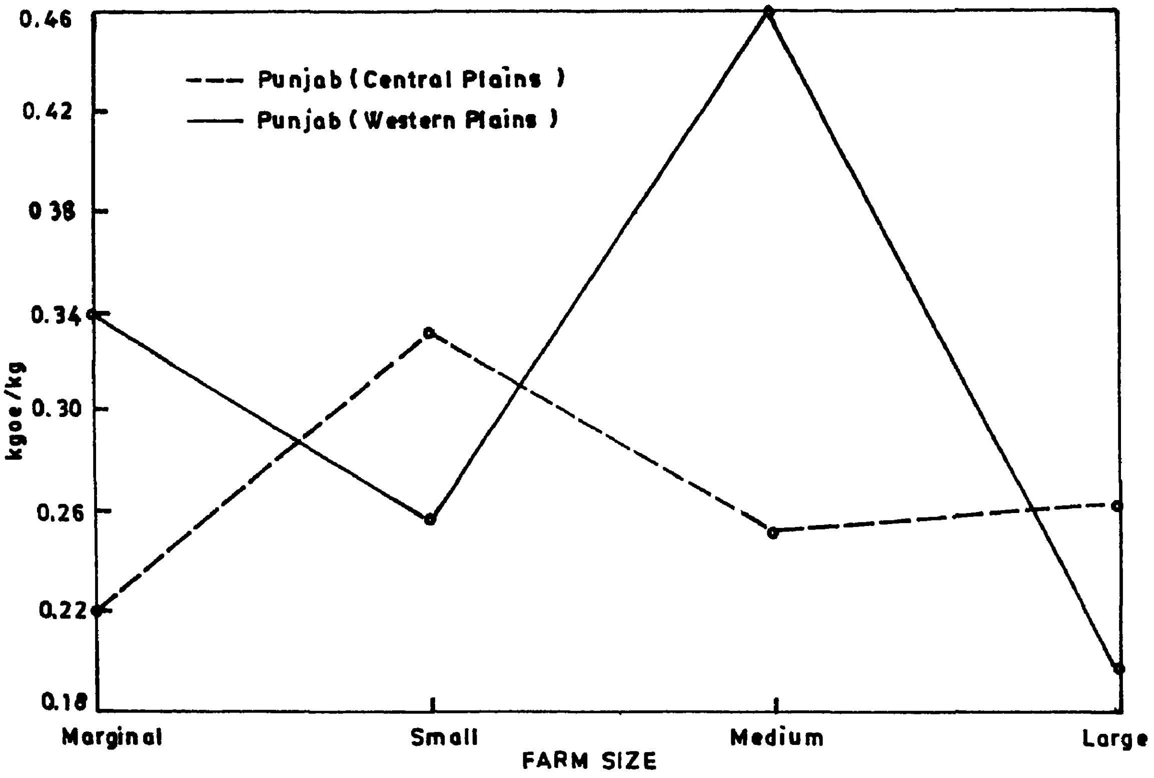


FIG. 2.2(b) DIRECT ENERGY INTENSITY OF WHEAT CULTIVATION

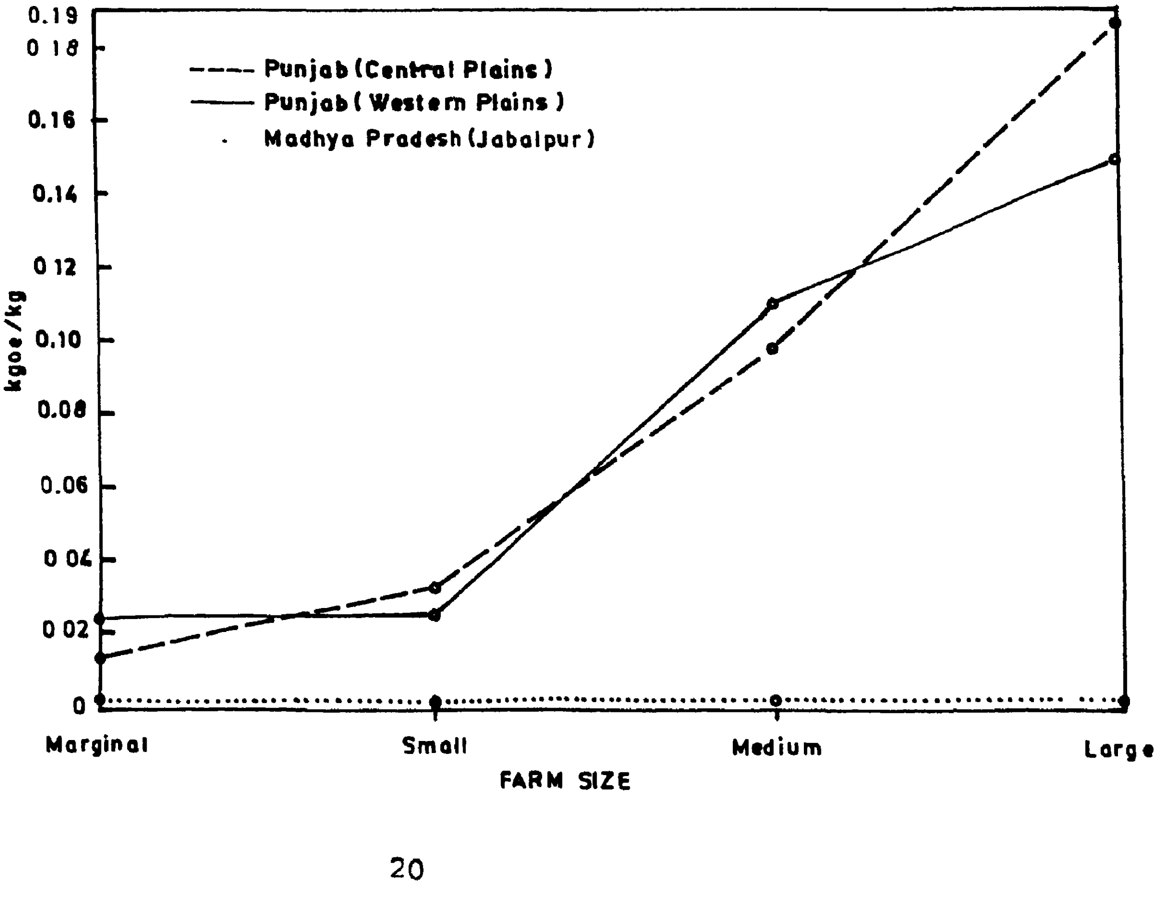


FIG. 2.3 ENERGY INTENSITY OF PADDY CULTIVATION IN PUNJAB

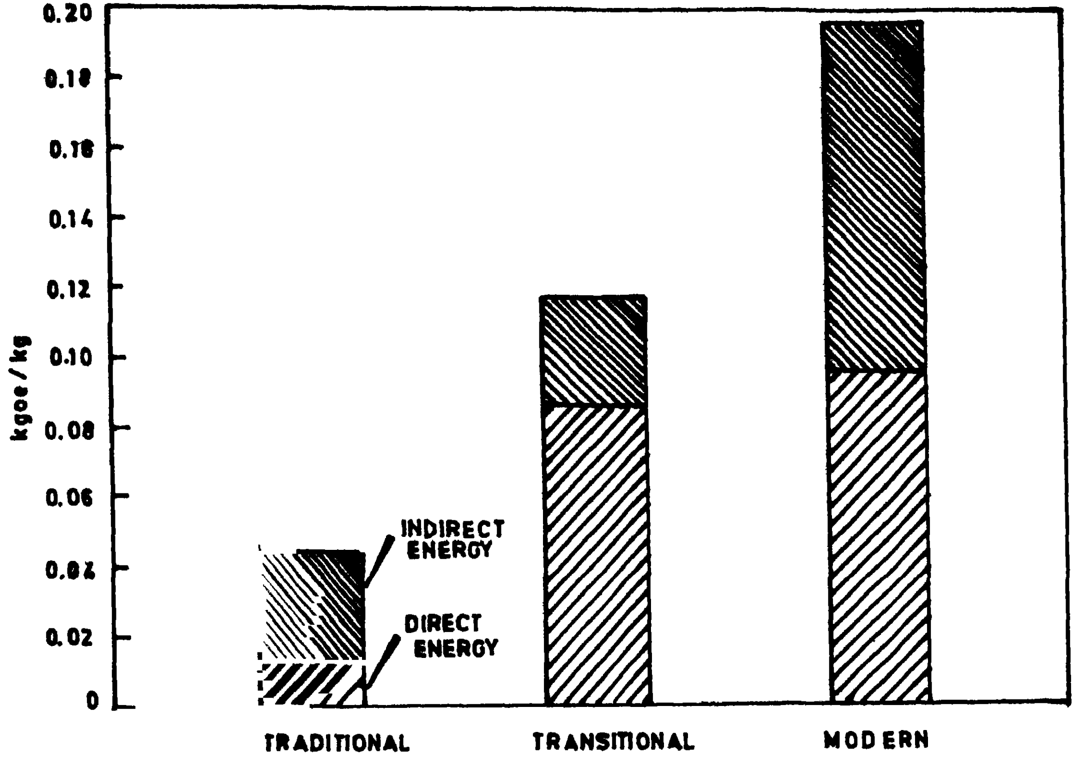


FIG. 2.4 ENERGY INTENSITY OF WHEAT CULTIVATION IN PUNJAB

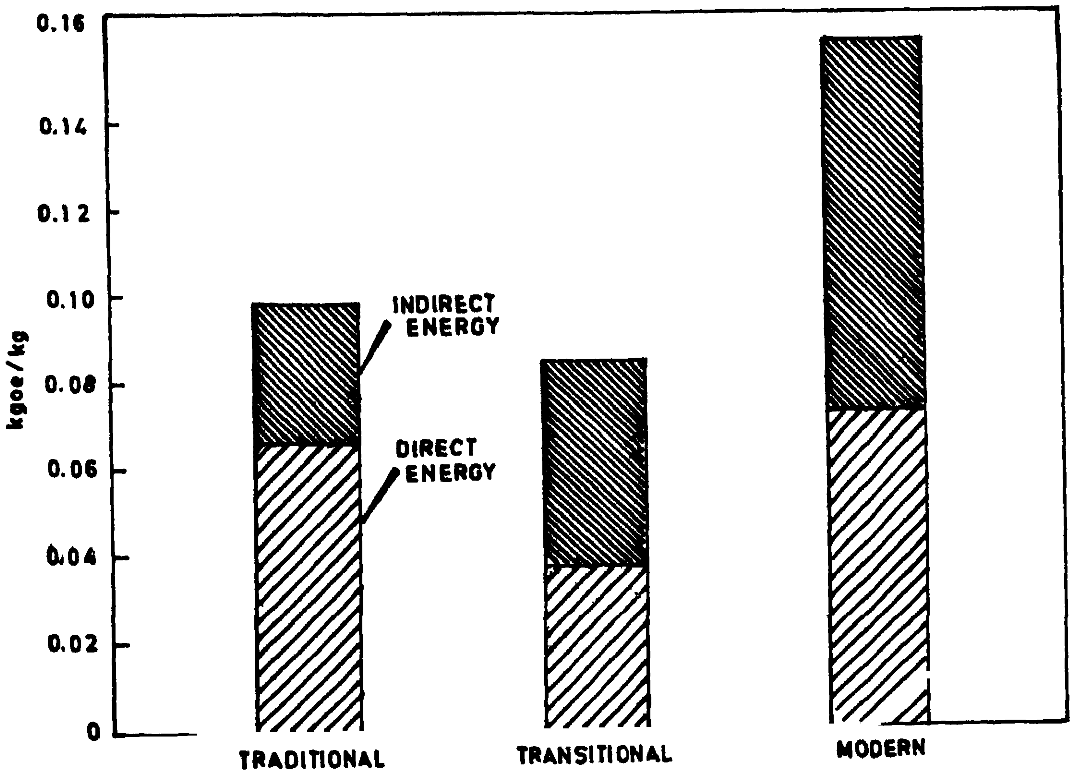


FIG. 2.5 ENERGY INTENSITY OF PADDY CULTIVATION IN NINE MAJOR STATES

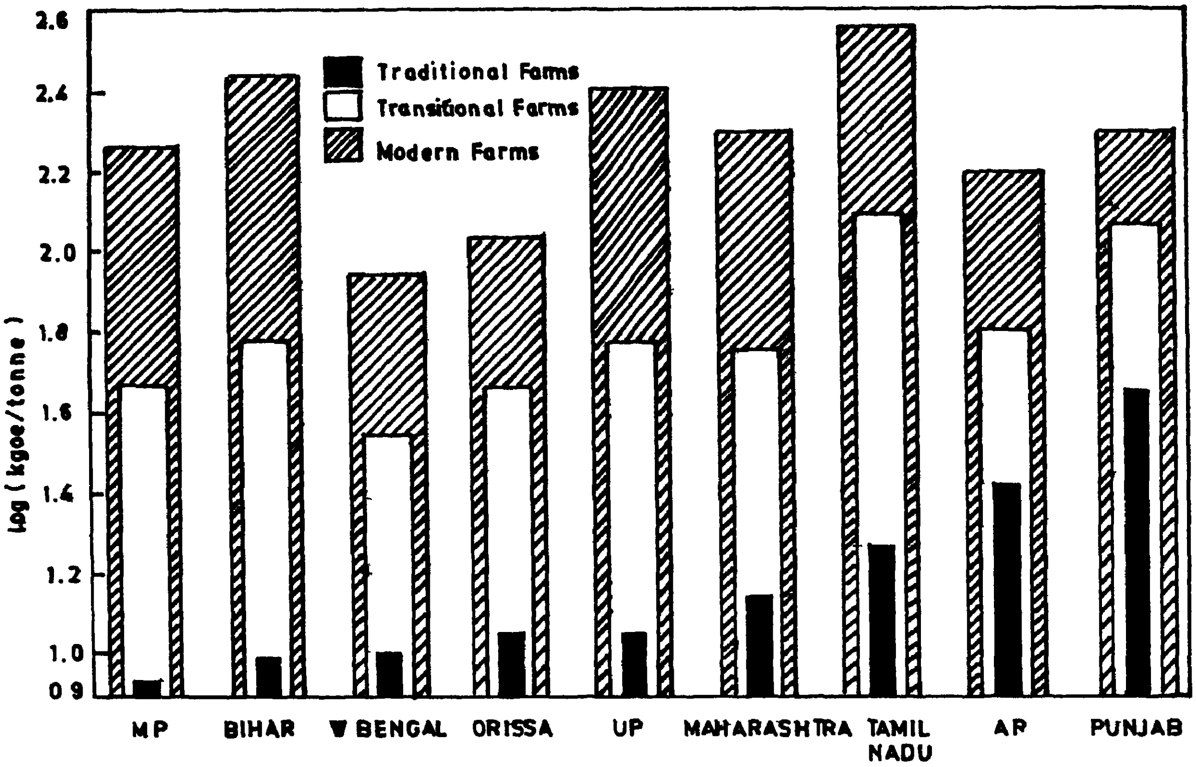


FIG. 2.6 ENERGY INTENSITY OF WHEAT CULTIVATION IN NINE MAJOR STATES

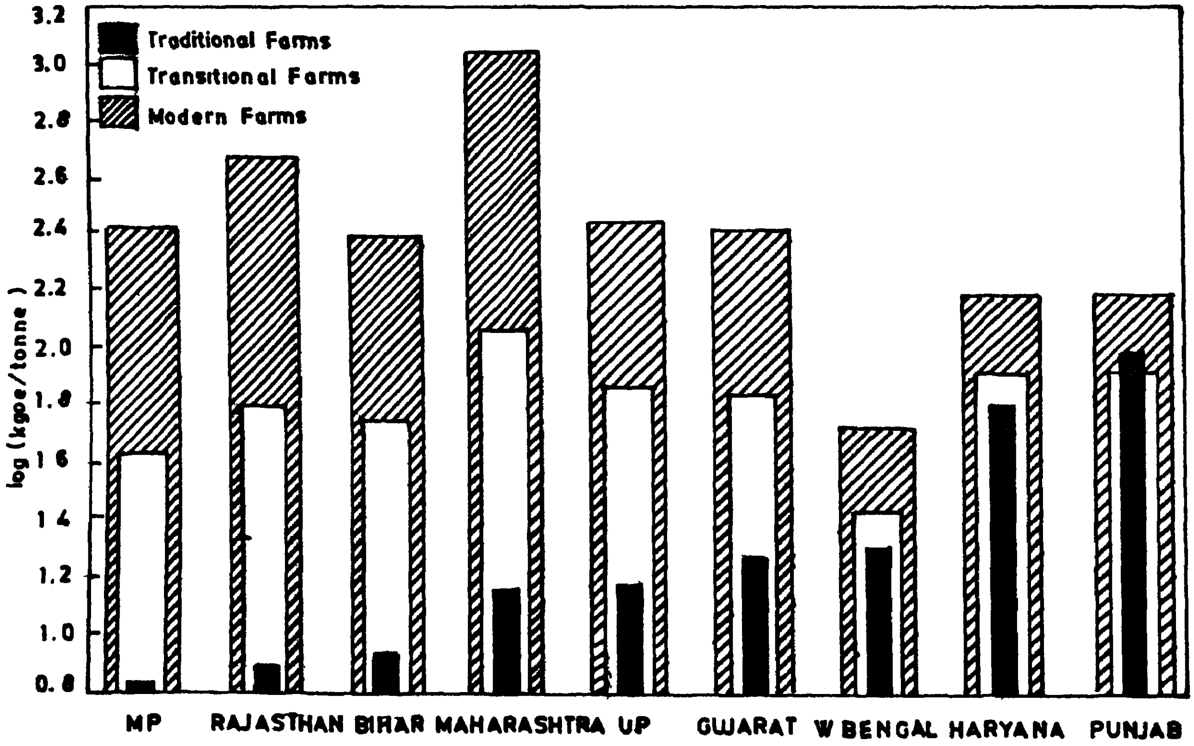


FIG. 2.7 ENERGY INTENSITY OF PULSES CULTIVATION IN EIGHT MAJOR STATES

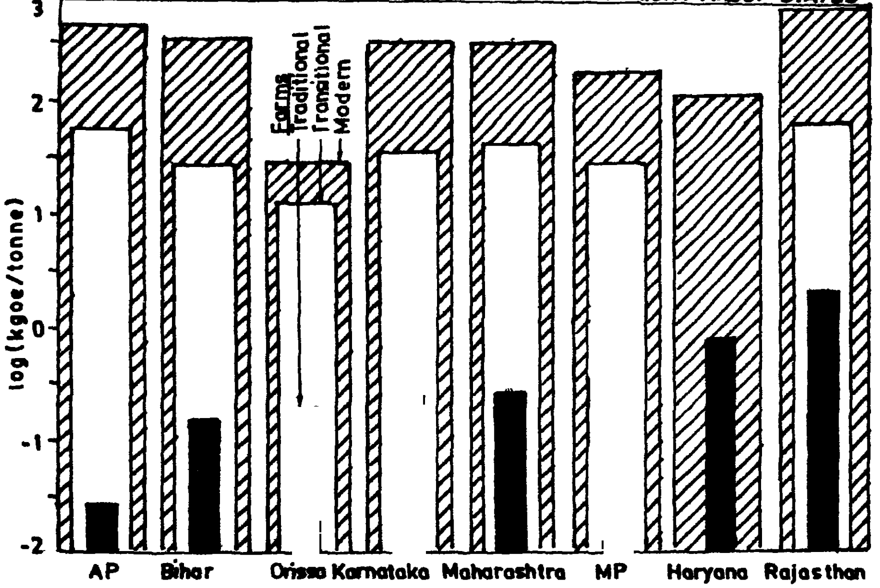


FIG. 2.8 ENERGY INTENSITY OF SUGARCANE CULTIVATION IN NINE MAJOR STATES

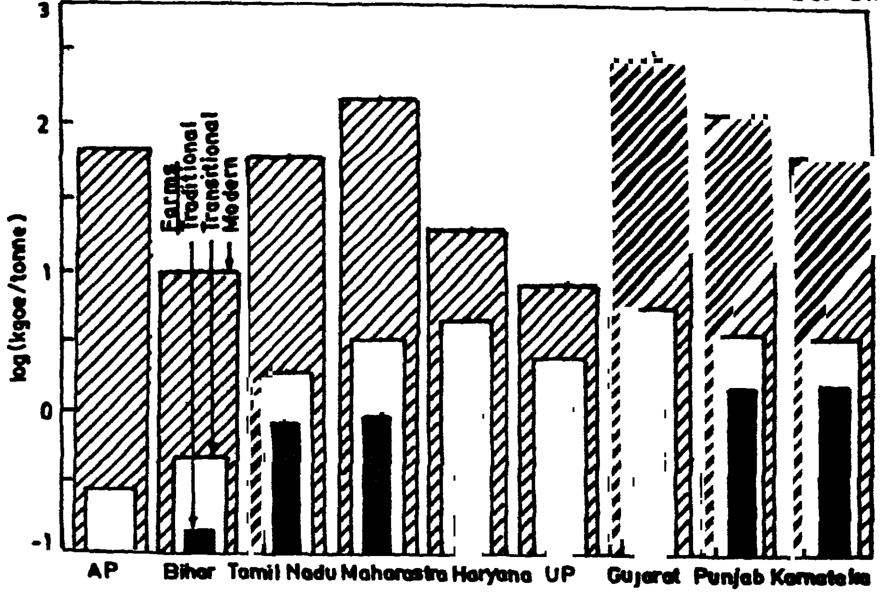


FIG. 2.9 ENERGY INTENSITY OF OILSEEDS CULTIVATION IN NINE MAJOR STATES

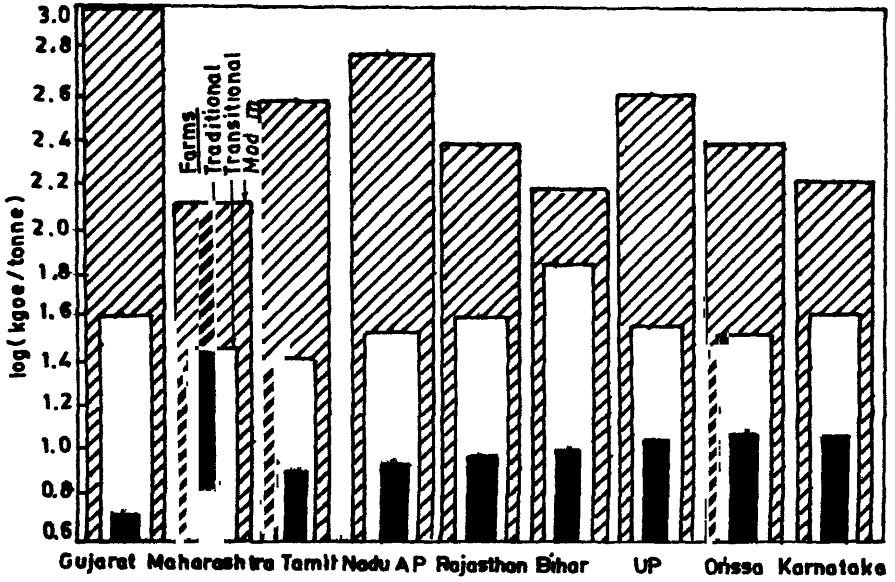
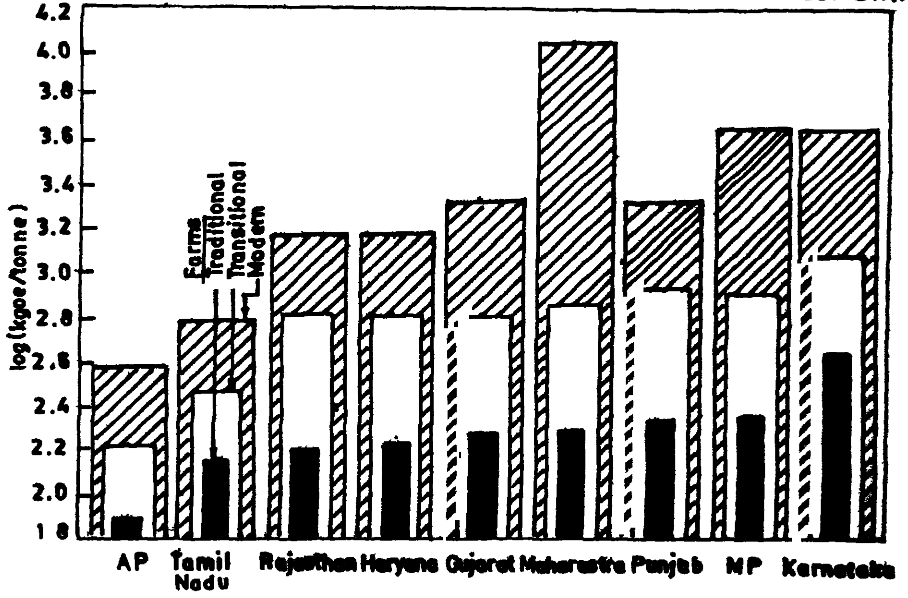


FIG. 2.10 ENERGY INTENSITY OF COTTON CULTIVATION IN NINE MAJOR STATES



III. INDUSTRY

3.1 Introduction

Industry is the major energy consuming sector in the country. It is a very diverse sector, comprising the manufacture and processing of various types of goods, with varying degrees of technical sophistication and a wide range of energy consumption levels per unit of output.

The energy utilization pattern in the industrial sector may be studied at two levels: (i) the micro or enterprise level; and (ii) the macro sectoral and sub-sectoral levels. At the micro-level, energy flows through the various equipments and machinery in use in a particular industrial unit are accounted for. Such micro-level energy audits are usually quite detailed, and are conducted by plant engineers or/and consultants. However, a macro-level understanding of energy utilization patterns in a particular category of industry or in the sector as a whole, requires data which may be available in published secondary sources.

The scope of the present study clearly limits us to adopting the latter approach; although reference is made to some case-studies conducted by TERI towards documenting the energy use patterns in selected industrial establishments.

3.2 Overall Energy Intenstiy

Industries in India are classified as per the National Industrial Classification (NIC) 1970 code. Under this system of classification, manufacturing industries of a similar nature (in terms of main products and end uses) are categorized into 19 major groups. Each of the these groups is identified with a 2-digit number labelled 20 through 38[1]. These groups are then further broken down to groups of industries which are identified by a 3-digit number -- the first two digits of which identify the major group. A three-digit number representing a group industries is further broken down into a four-digit number that would label the type of industry belonging to a group of industries. This process of disaggregation may perhaps continue further, but reports published by the Annual Survey of Industries (Ministry of Planning, Government of India) do not provide information beyond the four-digit level of disaggregation.

Available data from the Annual Survey of Industries therefore permit an estimation of energy intensities in industry at different levels of disaggregation. Figure 3.1 depicts the energy intensity of the entire manufacturing sector, of industries which manufacture natural products (NIC code beginning with 2), and of industries which manufacture synthetic products (NIC code beginning with 3). Figure 3.1 clearly shows that the energy intensity of natural products manufacture has been substantially lower than the energy intensity of synthetic products manufacture. It may be noted

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1) In fact, the highest level of aggregation in manufacturing industries may be conceptualized to be: (i) natural product industries, whose code begins with '2'; and (ii) synthetic product industries, whose code begins with '3'.

while the value added by the two major categories of manufacturing industry (natural products and synthetic products) has been nearly equal since the early 1970s, the industries manufacturing natural products have consumed about 30% to 35% of the total energy consumed by the entire manufacturing sector; and those manufacturing synthetic products about 65% to 70%.

As one of the basic purposes of such an exercise using secondary data is usually to identify industries or industry groups which should receive a priority status for implementing energy conservation programmes, it is important to establish these priorities carefully. Clearly, a manufacturing industry which is characterized by a high energy intensity but a very low volume of output may not offer much opportunity for energy conservation -- for in terms of energy consumption, its share vis-a-vis the entire manufacturing sector may be quite low.

It is evident that categories of manufacturing industry which have high shares of energy consumption (as percentage of that in the entire manufacturing sector) would qualify as being priority industries for energy conservation. These industries may even have a relatively low energy intensity, but may be priority industries so long as they have large volumes of outputs (e.g., the textile industry).

In view of these considerations, an attempt is made to establish priority industries at the two- and three-digit levels of classification. The priority ranking is related to the share of energy consumption.

At the two digit level, the first five major groups of manufacturing industry, in descending order of priority, are: (i) basic metals and alloys (NIC CODE : 33); (ii) chemical and chemical products, excluding petroleum and coal products (NIC code : 31); (iii) cotton textiles (NIC code : 23); (iv) non-metallic mineral products (NIC code : 32); and (v) food and food products (NIC code : 20 and 21). These five major groups together account for nearly 75% of the overall energy consumption of the entire manufacturing sector.

At the three digit-level, the top ten groups of priority industries are: (i) iron and steel industries (NIC code : 330); (ii) cotton spinning, weaving etc. and finishing of cotton textiles (NIC code : 231); (iii) fertilizers and pesticides (NIC code : 311); (iv) cement and lime (NIC code : 324); (v) basic and industrial organic and inorganic chemicals (NIC code : 310); (vi) pulp, paper and paper board (NIC code : 280); (vii) foundries for casting and forging iron and steel (NIC code : 331); (viii) aluminium (NIC code : 335); (ix) turpentine etc. (NIC code : 316); and (x) spinning, weaving and finishing of other textile and synthetic fibres (NIC code : 247). These ten groups of industries account for about 60% of the energy consumption of the entire manufacturing sector.

Figures 3.2 and 3.3 show the evolution of the energy intensity of five major groups of priority industries at the 2-digit level, and intensities for the period 1973/74 through 1984/85 are estimated and presented in the figures. The energy intensities, in figures 3.2 and 3.3, as in figure 3.1, are computed as the ratio of respective energy consumption and value added, both in monetary terms[2]. The energy intensity of a certain category of industries may therefore be reduced by lowering the energy consumption (keeping the value added unchanged) or by an increase in the value added (keping energy inputs unchanged) or by suitable changes in both value added and energy inputs. The energy intensity thus computed is a ratio, and provides certain useful information, which however, needs to be interpreted carefully. It is important to note that prices of certain inputs (including energy products) and indsutrial outputs are administered by the Government, and the relative prices of various inputs to and outputs from the manufacturing sector may vary from year to year. This in fact, may be one of the reason that energy intensities thus computed have varied sharply from year to year. Besides, as the energy prices (particularly that of coal and electricity) vary from one state to another, the change in the spatial distribution of a particular category of industry during the 1973/74 to 1984/85

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2) Energy use is taken in monetary terms (and not in physical units or equivalent heating value units) because of data limitations. The Summary Results, which are published by ASI every year, give energy utilization data in monetary terms only.

time period, may also influence energy intensity thus computed. Another reason that estimated energy intensities have changed from year to year relates to the capacity utilization factors. This aspect is particularly important. An interesting factor observed is the general reduction in intensities in 1974/75; which is perhaps because of a reduction in energy use in that year.

In addition to these generalizations regarding evolution of energy intensities, other factors such as existing equipment, switching over to inherently efficient technologies, improvements in management practices etc. also influence energy intensities. Such issues may be discussed better with reference to particular types of industries. Sections 3.3 through 3.6 present the energy intensity profiles of iron and steel, cement and aluminium industries.

3.3 Iron and Steel Industry

The iron and steel industry is highly energy intensive. The primary iron and steel manufacturing sector may be considered to be comprising two types of units: (i) six integrated steel plants with a total ingot steel production capcity of 14.72 million tonnes (MMT) per annum; and (ii) nearly 200 electric arc furnaces known as mini-steel plants holding licenses/letters of intents, with a total annual capacity of 6.5 MMT of ingots/billets. Of these, 161 units,with an annual installed capacity of approximately 4.37 MMT were in production as on January 1988.

The six integrated steel plants include one plant operated by the Tata Iron and Steel Company (TISCO) and five plants under the Steel Authority of India (SAIL). The five SAIL plants are at Bhilai (4 MMT capacity), Bokaro (4 MMT capacity), Durgapur (1.6 MMT capacity), Rourkela (1.8 MMT capacity) and the Indian Iron and Steel Company (IISCO; 1 MMT capacity).

The energy intensity of the iron and steel industry is computed and presented in Figure 3.4. Intensity here (as also in sections 3.4 through 3.6) is defined as the ratio of energy consumption in kilogram of oil equivalent per kilogram of output. Figure 3.4 shows that the energy consumption intensity has varied substantially from 1970/71 to 1986/87. The intensity of the integrated plus mini-steel plants centered around 1.35 kgoe/kg of ingot steel; and the range for variations was about ± 7.5%. This variation from year to year reflects at least in part the capacity utilization factors. The variation in the intensity of ingot steel production from integrated plants has been higher during the period 1982/83 to 1986/87, from about 1.3 kgoe/kg to over 1.6 kgoe/kg. The rather high intensity in 1985/86 reflects largely the relatively low steel production in that year (Table 3.1).

In fact, except for 1985/86, the energy intensity of integrated steel plants has always been less than the intensity of the entire iron and steel industry, except in 1985/86. This observation perhaps suggests that not withstanding long gestation periods associated with establishing steel plants, and the need to reduce the demand/ supply gap, the integrated iron and steel plants should be preferred.

Furthermore, experience in operating large integrated iron and steel plants in several developed nations suggests that the energy intensity of steel production could be reduced further by incorporating certain conservation measures. Most important of such measures include : (i) in the iron making stage, to increase inter usage, having higher blast temperatures to reduce coke rates, recovering heat from top gases to generate power, reducing slag volume, and sizing the iron-ore properly; (ii) in the steel making stage, having better combustion and draft control and improving the thermal efficiency of the regenerator; and (iii) in steel processing, conserving the heat energy of hot ingots and improving the construction of soaking pits and refractories.

3.4 Cement

During the Sixth FYP period, the Indian cement industry recorded significant growth. Production grew at 10% per annum, and installed capacity at 13%. By the end of the Seventh FYP period, the installed capacity is anticipated to rise to about 62 MMT.

At present, the Indian cement industry produces thirteen varieties of cement, of which three comprise more than 95% of the total production; (i) ordinary portland cement; (ii) portland pozzolona cement; and (iii) portland slag cement.

The technology for cement manufacture has changed substantially in India, during the past three to four decades. While plants based on the wet process were established in the 1950s and early 1960s, those with dry process have been set-up thereafter. Dry process cement account for over 60% of the installed capacity. The precalcinator technology has also now been introduced in India.

Electric power and coal are the major energy forms used in the cement industry, although some plants use furnace oil and lignite also. The cement industry accounts for over 10% of the manufacturing sector's coal consumption and over 6% of the sector's electricity consumption. Despite the fact that the share of installed capacity of the inherently more efficient dry process technology has increased, the energy intensity of the cement industry has remained more-or-less unchanged since 1970/71 (Figure 3.5). In fact, the rise in intensity during the early 1980s reflects partly the fact that several new cement plants were being commissioned, and experienced some "teething problems" before their operations could be stabilized.

The energy consumption norms in India, in fact, have remained higher than what has been achieved internationally (Table 3.2). As no better process for cement manufacture, than the precalcination dry process is expected in the near future, the specific energy consumption can be lowered in India (as elsewhere in the world) only by incorporating better house-keeping at the plant level. In addition of course, as the new capacity additions are likely to be based on the precalcinator dry-process technology, the energy intensity of cement manufacture is likely to reduce in the coming years.

3.5 Aluminium

The primary aluminium industry is one of the most energy intensive industries. The major forms of energy used are electricity, coal, fuel oil and diesel oil. Besides, materials like petroleum coke, and coal tar pitch, which can be used as fuels, are also being consumed in large quantities. These direct and indirect energy forms together with other raw materials such as bauxite, cryolite and aluminium flouride account for around 85% of the total production cost of aluminium metal.

The aluminium inudstry in India, which began with the production of household utensils from imported sheets in the thirties, has made considerable progress in the last five decades. At present six smelters are being operated by four companies: (i) The Bharat Aluminium Company Ltd. (BALCO) at Korba in Madhya Pradesh; (ii) The Indian Aluminium Company (INDAL) at Belgaum in Karnataka, Hirakud in Orissa and Alwaye in Kerala; (iii) The Hindustan Aluminium Company Ltd

(HIDALCO) at Renukoot in Uttar Pradesh; and (iv) the Madras Aluminium Company Ltd. (MALCO) at Mettur in Tamil Nadu. The smelters at Korba, Belgaum, Renukoot and Mettur are integrated plants, i.e., all process steps for converting bauxite to the finished product take place at the same location. For the INDAL smelters at Alwaye and Hirakud, aluminia is the input material -- this alumina is produced at INDAL's alumina plant at Muri in Bihar. The total smelting capacity is 362,000 tonnes per annum.

Aluminium is being increasingly used by the country's inudstries in applications such as electric transmission lines, household and consumer durables, transport, building and construction, canning and packaging etc. The consumption of alumina has always been greater than domestic production, necessitating imports to be made from other countries.

The production of primary aluminium comprises three major steps : mining of bauxite, converting bauxite to alumina and converting alumina to aluminium.

All primary aluminium producers have their own captive bauxite mines. Bauxite mined in the country, though mainly of the trihydrate type, is often found mixed with varying amounts of monohydrate which is difficult to process. The silica content, which also affects the performance of the alumina plant, is also higher in Indian bauxite. In contrast, the bauxite mined in other countries is either of the trihydrate or monohydrate type with comparatively lower silica content.

Depending on the scale of mining operations, bauxite is mined by one of the following three methods - manual, semi-mechanized or mechanized. The mined bauxite is transported to alumina plant directly or to the railhead by aerial ropeways or by trucks. From the railhead, the bauxite is moved to the plant site by rail.

Energy in the form of diesel oil is consumed in semi-mechanized or mechanized mining as well as in transporting the bauxite to the alumina plant. Electricity, which is mainly used for lighting, is also utilised in some mines for other purposes such as crushing bauxite and transporting it through aerial ropeways.

The Bayer process is the only process used for the manufacture of alumina in the country. The energy consumed in the alumina plant is in the form of fuel oil, coal and electricity. The average specific energy consumption figures of Indian plants in comparison with some plants in other countries are given in Table 3.3. It is clear that the specific energy consumption in India is high relative to that of some other countries.

The Hall-Heroult electrolytic reduction process is used for the reduction of alumina into aluminium. Both prebaked and Soderberg anodes are employed by the industry. Electricity is the only direct form of energy used in smelters. The average electricity consumption per tonne of aluminium in Indian plants is around 17,580 kWh, as compared to around 15,600 kWh in the Western countries. The higher specific electricity consumption is mainly due to technological limitations and inefficient operation owing to frequent power cuts.

The molten aluminium metal obtained from the smelter is either cast into ingots, billets and continuous strips, which are used as starting materials in rolling and extrusion, or cast directly into electrical and commercial grade rods. The specific energy consumption figures per tonne of finished product for a particular unit are given in Table 3.4.

On the whole, the Indian aluminium plants consume more raw materials and energy compared to their counterparts abroad. This is partly due to the fact that the industry has to cope with poor raw materials, and inadequate and unsteady power supply. Efforts to reduce consumption of raw materials and energy are being made by all the units, though on different scales. Owing to these efforts, units like HINDALCO and INDAL have been able to reduce their raw materials and energy consumption to a considerable extent, and have reached consumption levels which are nearly equal to that of the best plants overseas.

Table 3.1 : Integrated Iron and Steel Plants

Year	Ingot Steel Production in Integrated Plants		
	MMT	% of total ingot production	Intensity (kgoe/kg)
1982/83	8.625	86.05	1.3099
1983/84	7.884	75.57	1.3931
1984/85	8.144	76.48	1.334
1985/86	7.038	58.50	1.620
1986/87	8.761	72.83	1.270

Table 3.2 : Energy Consumption for Cement Manufacture*

Process	Energy Type	Indian Scenario	World Scenario
Wet	Electricity (kWh/tonne)	114	87
	Thermal (toe/tonne)	0.163	0.122
Dry	Electricity (kWh/tonne)	155	111
	Thermal (toe/tonne)	0.096	0.075

* Data for 1983/84.

Source : TERI data-files.

Table 3.3 : Energy Intensity of Alumina Production (kgoe/kg)

Energy Form	India	Australia	Guinea	Jamaica
Thermal				
Calcination	0.1221	0.1200	0.1200	0.1200
Steam	0.3432	0.3539	0.3180	0.3897
Electrical	0.0306	0.0203	0.0203	0.0203
Total	0.4958	0.4942	0.4583	0.5300

Table 3.4 : Energy Consumption per unit of Finished Product in the Aluminium Industry (kgoe/kg)

Product	
Rolled Product	0.3406
Extruded Product	0.3404
Wire Rod	0.0847

FIG. 3.I ENERGY INTENSITY OF MANUFACTURING INDUSTRY

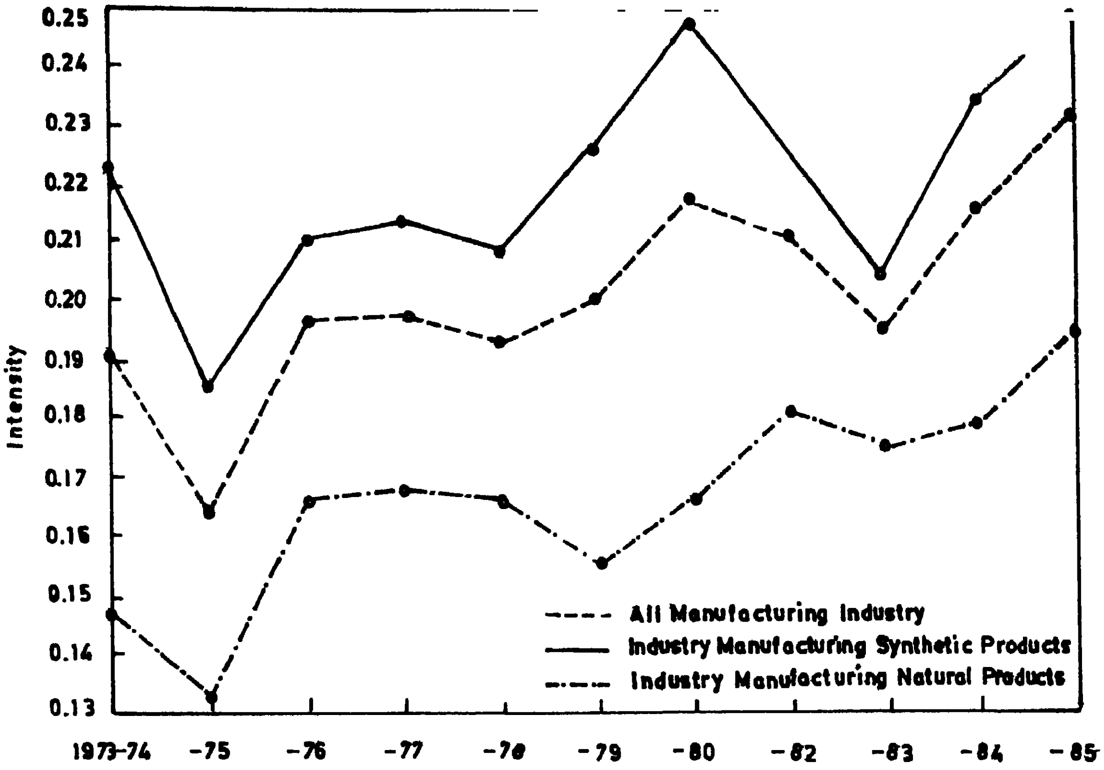


FIG 3.2 : ENERGY INTENSITY OF MANUFACTURING INDUSTRY AT 2 DIGIT LEVEL OF CLASSIFICATION

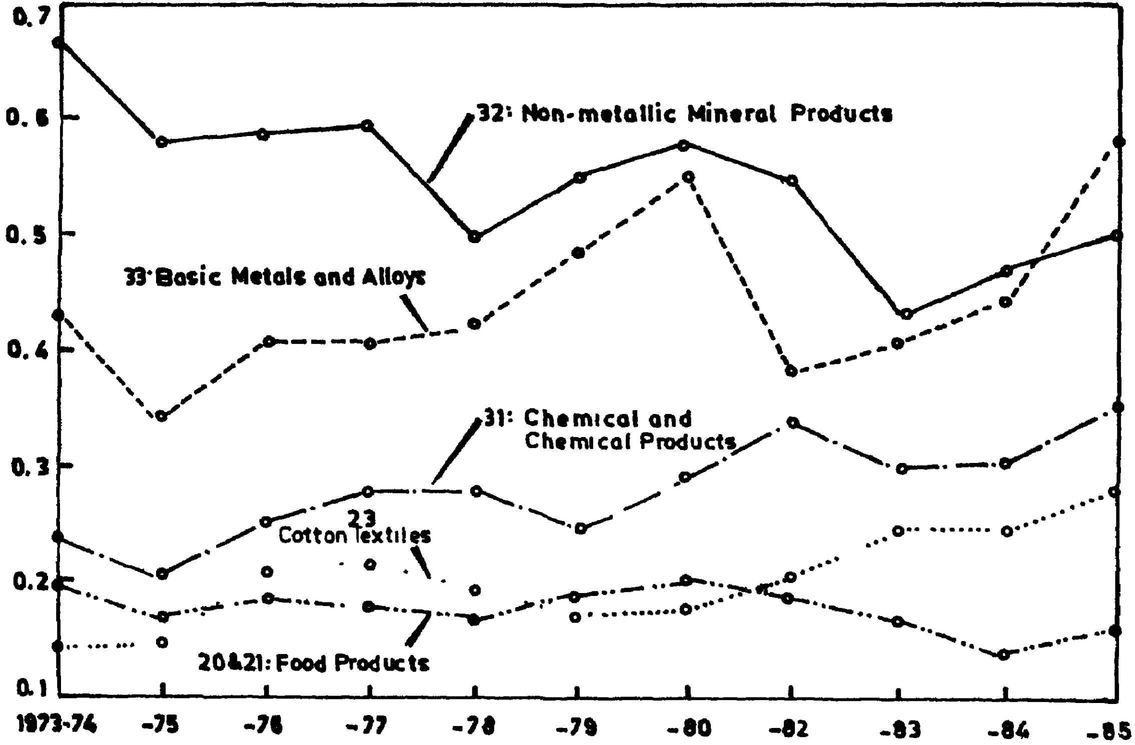


FIG. 3 3 · ENERGY INTENSITY OF MANUFACTURING INDUSTRY AT 3 DIGIT LEVEL OF CLASSIFICATION

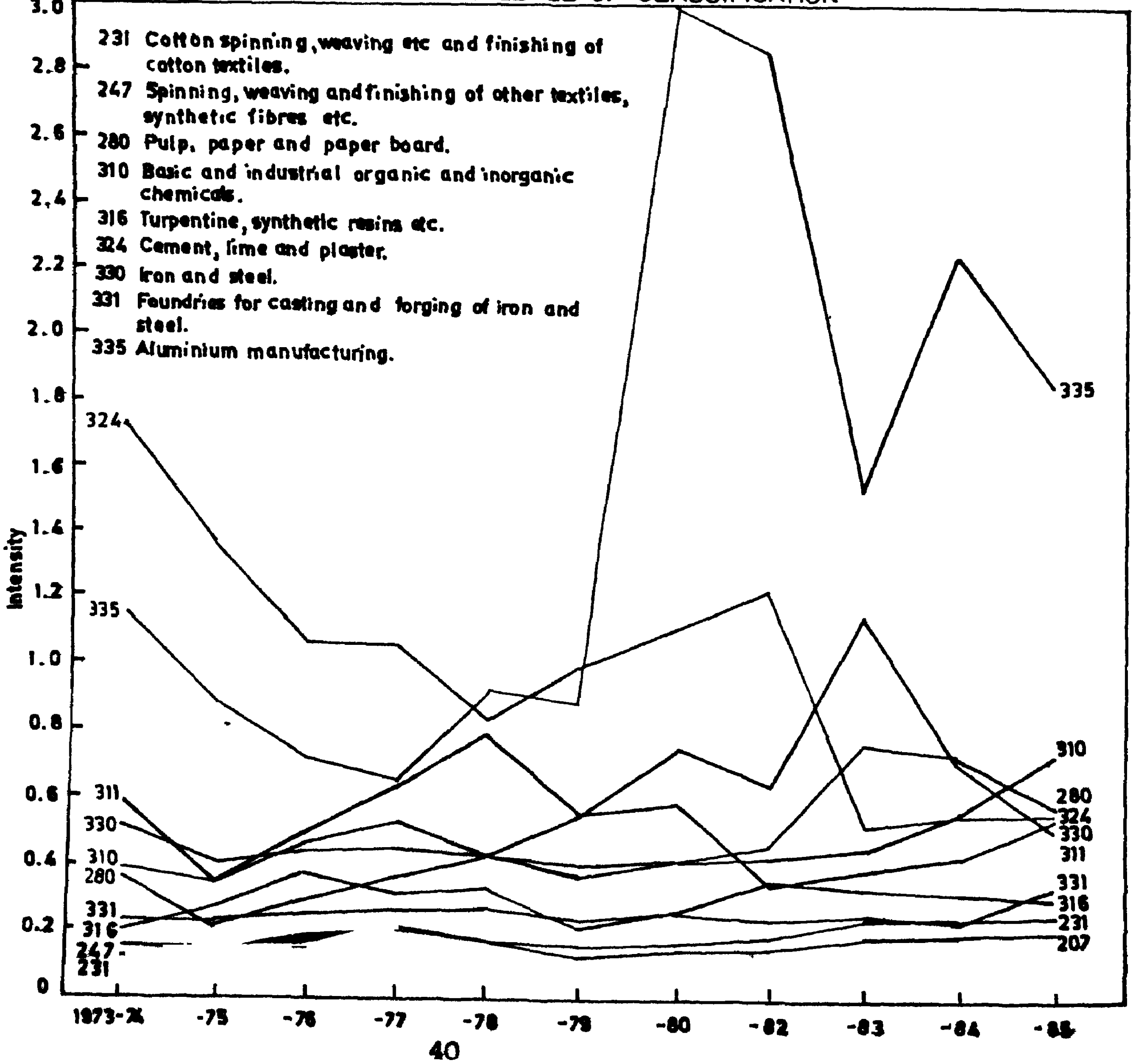


FIG. 3.4 ENERGY INTENSITY IN THE IRON & STEEL INDUSTRY

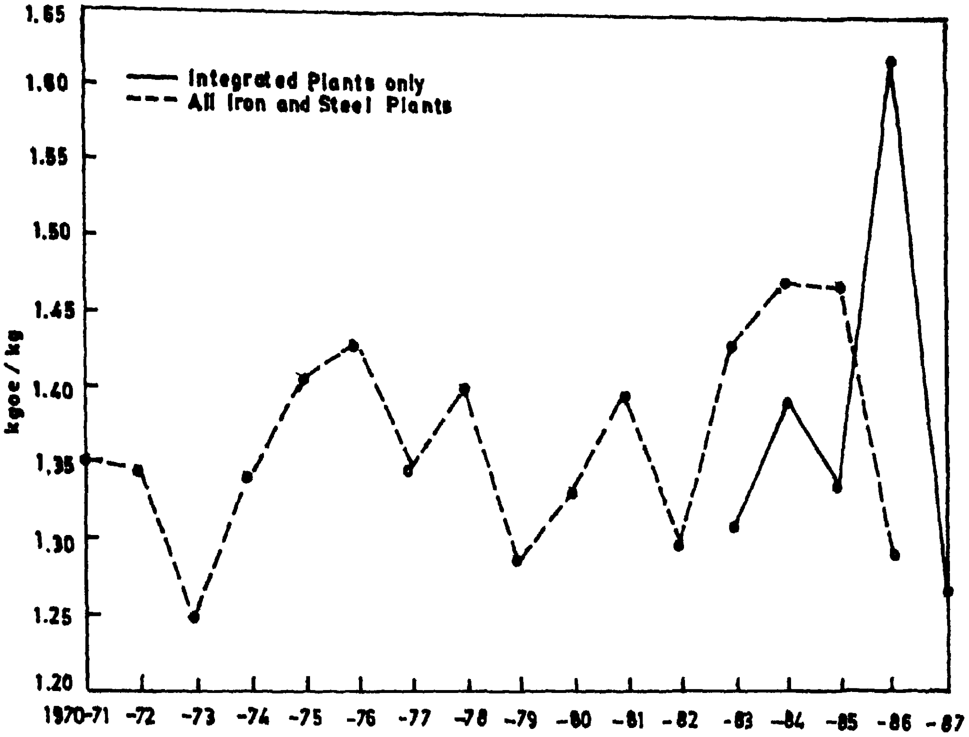
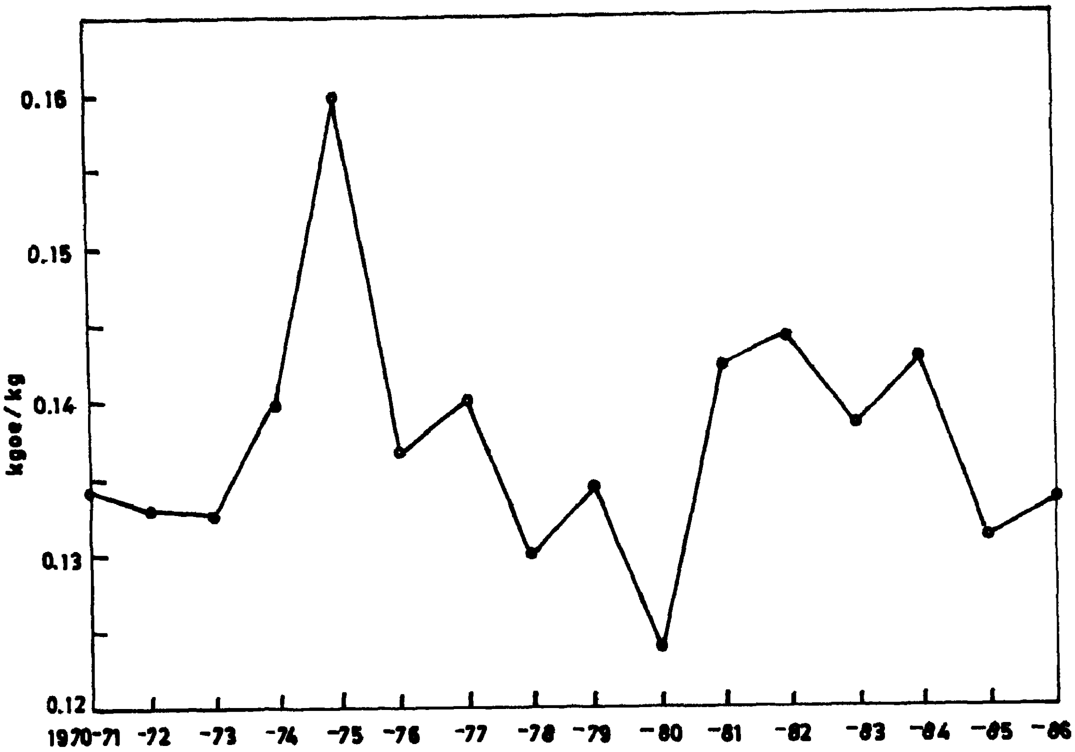


FIG.3.5 ENERGY INTENSITY IN THE CEMENT INDUSTRY



IV. TRANSPORT SECTOR

4.1 Introduction

The growth of the transport sector in India has been faster than overall economic growth during the past decade. As a fraction of total GDP, the share of the transport sector increased from about 4.5% in 1976/77 to about 5.4% in 1984/85. Despite this, unlike other developing countries, the growth in transport energy consumption has not kept pace with increases in GDP. This observation perhaps suggests that a significant energy conservation programme has been successfully implemented. However, it is necessary to analyze the evolution of the structure of the transport sector more closely before such a conclusion may be drawn.

On the basis of data available for the years 1970/71 through 1984/85, the overall energy intensity of the transport sector is computed and presented in Figure 4.1. The declining trend is very clear; the overall energy intensity of the transport sector is estimated to have reduced substantially from about 0.47 kgoe/Rs (1980/81 prices) in 1970/71 to about 0.25 kgoe/Rs (1980/81 prices) in 1984/85. Major factors which underlie this trend are explored below.

4.2 Rail-Road Shift

Rail and road continue to be the two major modes of transport in India. However, as in other parts of the world, there has been a distinct shift towards road transport (and away from rail) in India as well. Although this shift may reflect the greater flexibility of road transport, particularly for short haul traffic, Government policy has also played a role. The railways' share of total public sector investment for transport fell from over 65% during the Third Five Year Plan (FYP) period (1961-66) to about 42% in the Sixth FYP period (1980-85). Some corrective action however, has been taken in the Seventh FYP period (1986-90), when the corresponding investment share for the railways increased to nearly 55%.

Investment in the railways has been directed largely towards standardization of gauges, extension of sub-urban lines, replacing steam locomotives by diesel and electric ones, and in electrifying certain densely traversed routes. Public sector investment in roads however, has been directed towards increasing both total and surfaced road lengths, and the development of district and rural roads was given special emphasis. This strategy for road development, coupled with considerable private investment in automobiles, 2/3 wheelers, buses and trucks has been responsible for the relatively fast growth of the road transport sub-sector.

It is important to note however, that road transport is more energy intensive than rail transport (Tables 4.1 and 4.2). It is therefore clear that other factors have contributed to a gradual decline of the overall transport sector intensity.

4.3 Energy Efficiency of Rail Transport

There has been a decrease in the overall energy efficiency of the rail transport system since 1970, but only due to a major shift in locomotive power from energy intensive steam locomotives to diesel and electric engines (see Figure 4.3). Traffic handled by steam locomotives declined from about 181.6 billion gross tonne-kilometres (bgtkm) in 1970/71 (about 47.6% of total rail traffic in 1970/71) to 63.3 bgtkm in 1986/87 (about 10% of total rail traffic in that year). This was made possible by : (i) a decline in the number of steam engines in service, from nearly 9400 in March 1971 to 4950 in March 1987, accompanied by an increase in the number of operating diesel plus electric engines from 1770 to 4550 during the same sixteen year time period; and (ii) decrease in the average annual utilization rate of steam engines, from an estimated 19.35 million gross tonne-kilometres (mgtkm) in 1970/71 to 12.78 mgtkm in 1986/87, accompanied by a rise in the combined average annual utilization of diesel and electric engines from 117.85 mgtkm to 123.92 mgtkm during the same time period.

The latter point probably is the reason for the increase in the average intensity of steam locomotion since 1970/71 (see Figure 4.2). In fact, steam locomotives have been used increasingly on short haul routes with frequent stoppages, and for shunting purposes. There are no significant changes in average diesel and electricity use intensities for locomotion. It is therefore clear that once all steam locomotives are out of service, further overall improvements in rail transport efficiency would be possible only through design improvements and better management.

4.4 The Changing Nature of Road Transport

The data-base for vehicular traffic and energy use in the road transport sub-sector is very weak. For various types of road vehicles, little is known other than their population (the rise in the number of registered cars/taxis and two-wheelers is shown in Figure 4.5). However, some reasonable estimates have been made by Engineering Consultants Pvt. Ltd. (ECPL) in a study for the Department of Surface Transport (Roads Wing) of the Government of India in January 1987.

As far as mechanized road passenger and freight transport is concerned, the above mentioned study identifies the factors which have determined traffic throughput by various types of vehicles. Where possible, time series variations have also been estimated indirectly using related data (for instance, on tyre sales, average life of a tyre etc.). The detailed assumptions are not listed here, and may be obtained directly from the above mentioned project report. Some of the underlying assumptions regarding occupancy ratios of buses and average loading of trucks are shown graphically in Figures 4.6 and 4.7 respectively.

According to the ECPL (1987) study, total mechanized road freight traffic (through HCV and LCV trucks, three-wheelers and agricultural tractors) increased from 27.17 billion tonne-kilometres (btkm) in 1961 to 240.06 btkm in 1985, at the rate of 9.5% per annum. HCV trucks continue to account for 96% of freight traffic on roads. Likewise, total mechanized road passenger traffic (through cars/taxis, two- and three-wheelers, and buses) also increased from 94.8 billion passenger kilometres (bpkm) in 1961 to 853.7 bpkm in 1985, at the rate of 9.6% per annum.

According to estimates based on information available in the ECPL (1987) study, the share of mechanized road passenger traffic through private means is estimated to have increased from less than 13% in 1970/71 to over 14% in 1986/87. As private mechanized vehicles of road passenger transport are fueled largely by petrol (gasoline), it is interesting to study the evolution of the petrol consumption intensity. Figure 4.4 shows that petrol consumption intensity decreased from over 0.05 kgoe/passenger-kilometre (p-km) in 1970/71 to less than 0.02 kgoe/p-km in 1986-87, which apparently indicates a very substantial efficiency improvement in private road motor vehicles. However, this is not really the case as more efficient models of cars and two-wheelers have been introduced in India only during the past five years or so. In fact, just like in rail transport, the overall intensity reduction is due largely to a structural change in the sub-sector -- this time, a relatively rapid increase in the population of two- and three-wheelers which are inherently less energy intensive than cars or taxis. According to estimates made by (and on the basis of) the ECPL (1987) study, the share of private road passenger traffic through cars/taxis in total private road passenger traffic declined from over 81% in 1970/71 to about 53% in 1986/87.

For purposes of comparing the intensities of road transport directly with the railways, the passenger traffic may be expressed in terms of equivalent freight tonne-kilometres (t-km). Using a conversion factor of 0.1 t-km/p-km, it is observed that the overall road transport intensity has also declined considerably, from 0.057 kgoe/t-km to less than 0.04 kgoe/t-km during the 1970/71 to 1986/87 period. It may be noted however, that energy intensities per tonne-kilometre of road traffic have remained substantially higher than the corresponding intensities in the railways.

As far as the non-mechanized modes of road transport are concerned, their contribution, in terms of passenger-kilometres or tonne-kilometres is estimated to be marginal. According to the estimates made by the ECPL (1987) study, cycle-rikshaws and bicycles accounted for 65 bpkm of passenger traffic in 1985 (about 7.6% of road passenger traffic through mechanized means); and animal drawn carts accounted for 3.4 btkm of freight traffic in the same year (about 1.4% of road freight traffic through mechanized means). The utilization of useful human and animal muscle power for propulsion in such vehicles is usually difficult to quantify.

4.5 Energy Efficiency Trends in Shipping

As discussed in TEDDY 1988, neither are data on freight tonne-kilometres transported through water available, nor is it possible to distinguish from available data on cargo handled at ports, the tonnage of exports/imports, or tonnage for movement from one port to another along the Indian coastline. Therefore, energy intensity estimates are expressed only in terms of kgoe per unit value added. It is clear from Figure 4.8 that energy intensity of water transport has decreased substantially since 1970/71: from 0.103 kgoe/rupee of value added (1980/81 prices) in 1970/71 to 0.058 kg/rupee in 1984/85. It is interesting to note, that this reduction in intensity is accompanied by an increase in the share of consumption of diesel oils -- which is related to the fact that the number of diesel powered vessels (of gross registered tonnage less than 3000) has increased most rapidly.

4.6 Energy Efficiency Improvements in Air Transport

Energy efficiency improvements in air transport have been most spectacular. This is due to the introduction of Airbus and Boeing 737 aircraft on inland flights, and the gradual phase-out of Caravelle, Viscount and Dakota aircraft. The relative increase in the number of revenue flying hours of jet aircraft is highlighted in Figure 4.9.

Although it is clear that energy intensity of air travel within India has reduced considerably since 1970/71, it is not possible to quantify this on the basis of ATF sales. This is because ATF is also sold to Air India, international airlines which schedule their flights through India, chartered aircraft etc; and time-series data for the break-up of ATF sales are not available. The energy intensities are therefore again estimated in terms of kgoe per unit value added, and presented in Figure 4.8: a gradual reduction from nearly 1 kgoe/rupee of value added (1980/81 prices) in 1970/71 to about 0.4 kgoe/rupee in 1984/85 is observed.

Table 4.1 : Energy Intensity of the Railways (kgoe/gross t-km)

	Steam	Diesel	Electricity*	Total
1970/71	0.0387	0.0036	0.0016	0.0196
1971/72	0.0395	0.0036	0.0018	0.0190
1972/73	0.0395	0.0036	0.0019	0.0182
1973/74	0.0432	0.0038	0.0017	0.0184
1974/75	0.0440	0.0037	0.0016	0.0179
1975/76	0.0428	0.0037	0.0015	0.0165
1976/77	0.0420	0.0035	0.0016	0.0146
1977/78	0.0442	0.0036	0.0016	0.0145
1978/79	0.0489	0.0035	0.0016	0.0144
1979/80	0.0515	0.0035	0.0017	0.0139
1980/81	0.0550	0.0036	0.0016	0.0135
1981/82	0.0566	0.0036	0.0015	0.0116
1982/83	0.0550	0.0037	0.0015	0.0108
1983/84	0.0577	0.0037	0.0015	0.0105
1984/85	0.0579	0.0036	0.0015	0.0098
1985/86	0.0564	0.0036	0.0014	0.0089
1986/87	0.0548	0.0037	0.0014	0.0081

* Including suburban passenger traffic.

Note : Share of traffic handled by steam, diesel and electric locomotives in 1970/71 was 46.5%, 35.2% and 18.3% respectively. The corresponding shares in 1985/86 were 11.2%, 57.5% and 31.3%.

Source : (i) Railway Board (GOI), Indian Railways: Annual Statistical Statements, various issues; and (ii) Central Electricity Authority, Public Electricity Supply : All India Statistics (General Review), various issues.

Table 4.2: Energy Intensity of Road Transport

Year	Diesel Use Intensity (kgoe/t-km)a)	Petrol Use Intensity (kgoe/p-km)b)	Overall Intensity (kgoe/t-km)c)
1970/71	0.0410	0.0529	0.0570
1971/72	0.0364	0.0477	0.0509
1972/73	0.0386	0.0373	0.0499
1973/74	0.0392	0.0417	0.0534
1974/75	0.0432	0.0319	0.0534
1975/76	0.0447	0.0314	0.0542
1976/77	0.0422	0.0300	0.0514
1977/78	0.0391	0.0278	0.0478
1978/79	0.0380	0.0276	0.0465
1979/80	0.0407	0.0249	0.0481
1980/81	0.0386	0.0235	0.0454
1981/82	0.0350	0.0222	0.0411
1982/83	0.0339	0.0215	0.0398
1983/84	0.0334	0.0207	0.0393
1984/85	0.0327	0.0202	0.0387
1985/86	0.0336	0.0196	0.0397
1986/87	0.0334	0.0192	0.0394

a) In buses and trucks.
b) In cars/taxis, 2 wheelers and autorickshaws.
c) Diesel and petrol use intensity for freight and freight equivalent of passenger traffic.

Source : (i) Engineering Consultants Pvt. Ltd., Report on Estimation of Total Road Transport : Freight and Passenger Movement in India for the Year 2000 A.D., "Prepared for the Department of Surface Transport (Roads Wing), GOI, January 1987; and (ii) Department of Petroleum (GOI), Indian Petroleum and Natural Gas Statistics, various issues.

FIG. 4.1 ENERGY INTENSITY IN TRANSPORT SECTOR

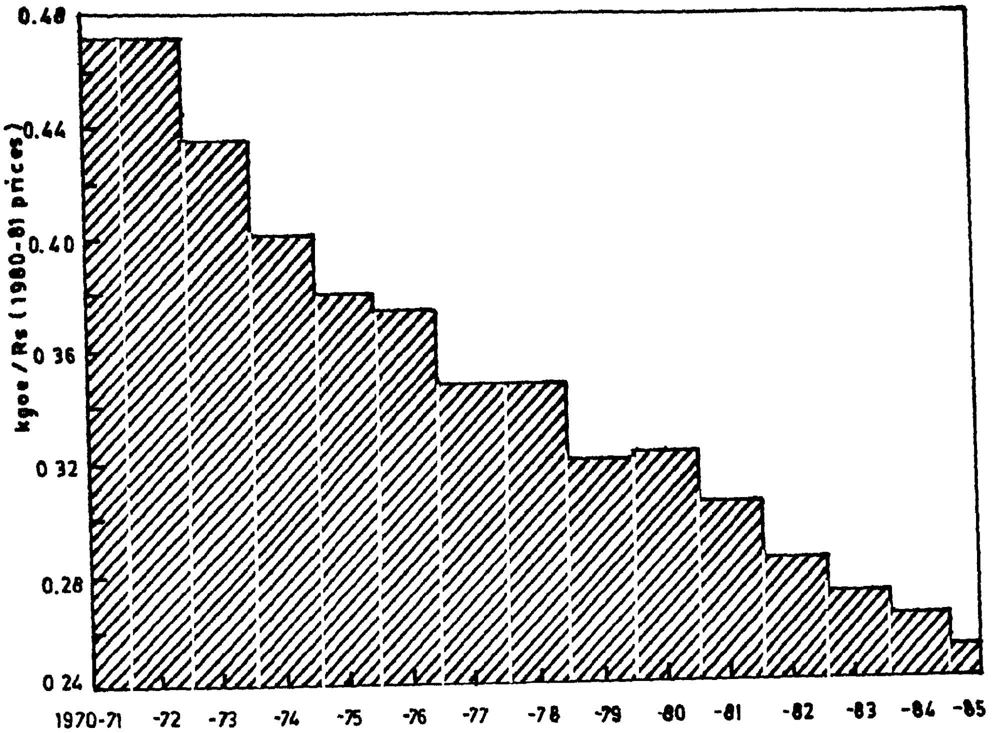


FIG. 4.2 ENERGY INTENSITY IN THE RAILWAYS

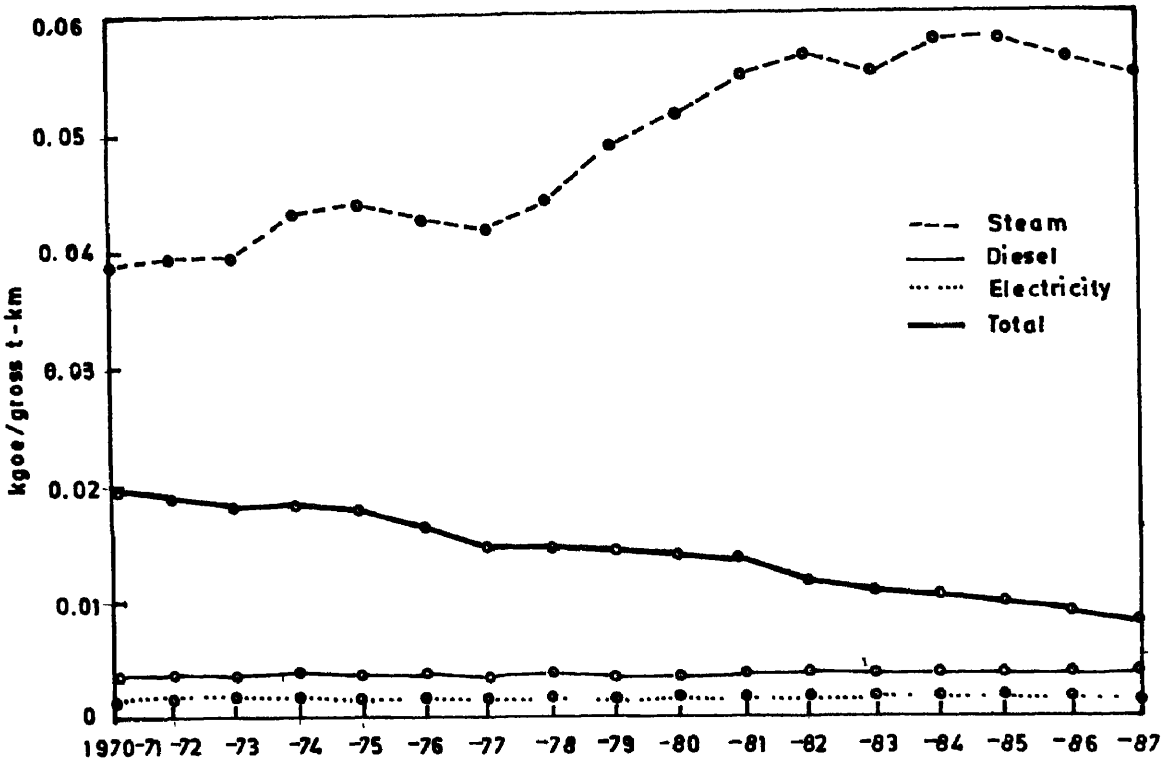


FIG 4.3 RAIL TRAFFIC BY STEAM, DIESEL & ELECTRIC LOCOMOTION

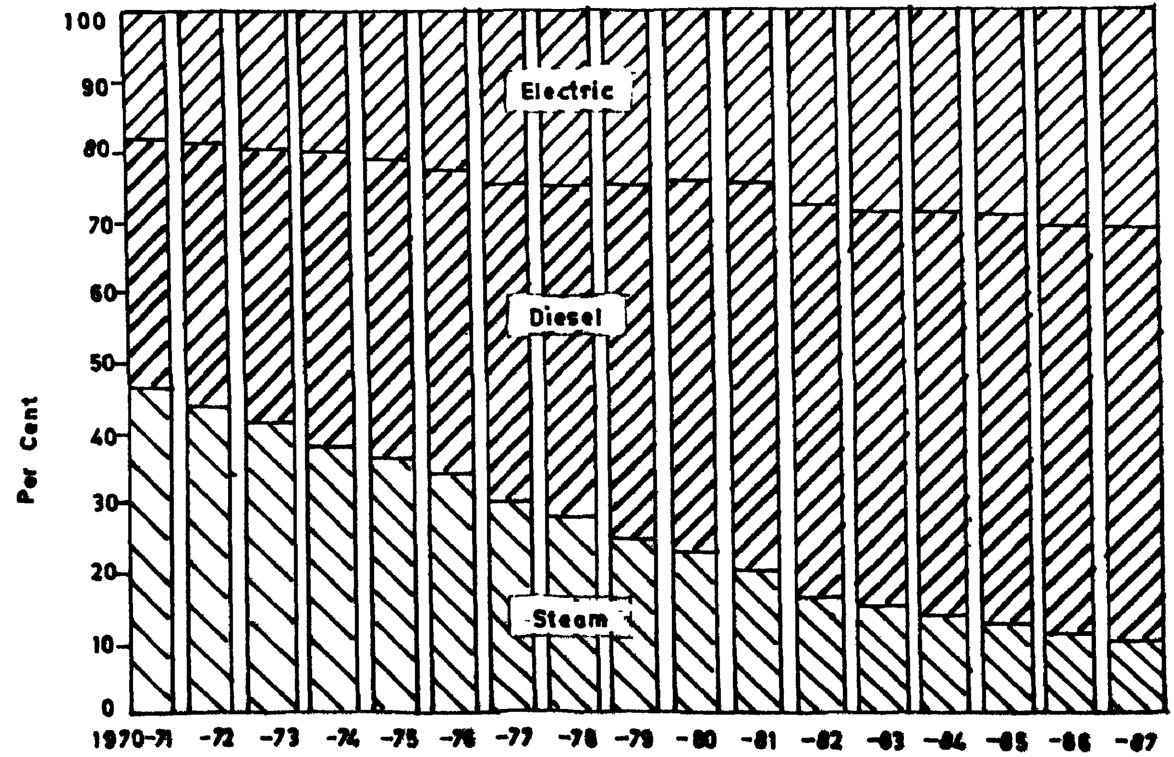


FIG.4.4 ENERGY INTENSITY IN ROAD TRANSPORT

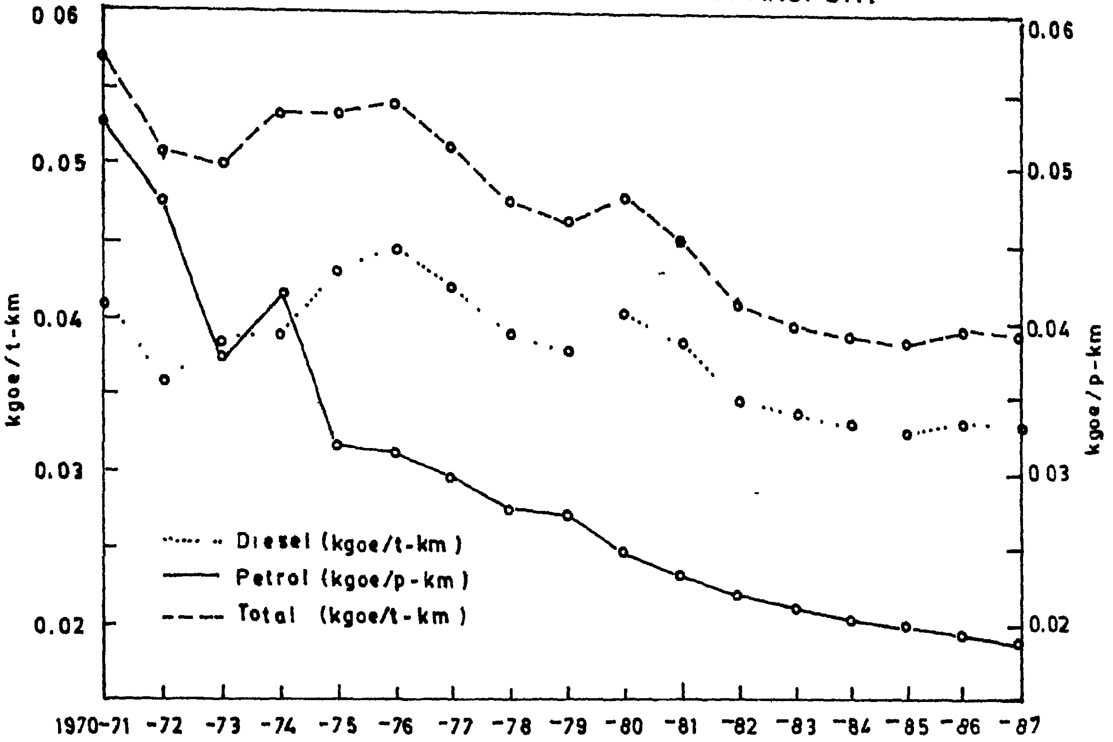


FIG. 4.5 POPULATION OF REGISTERED VEHICLES

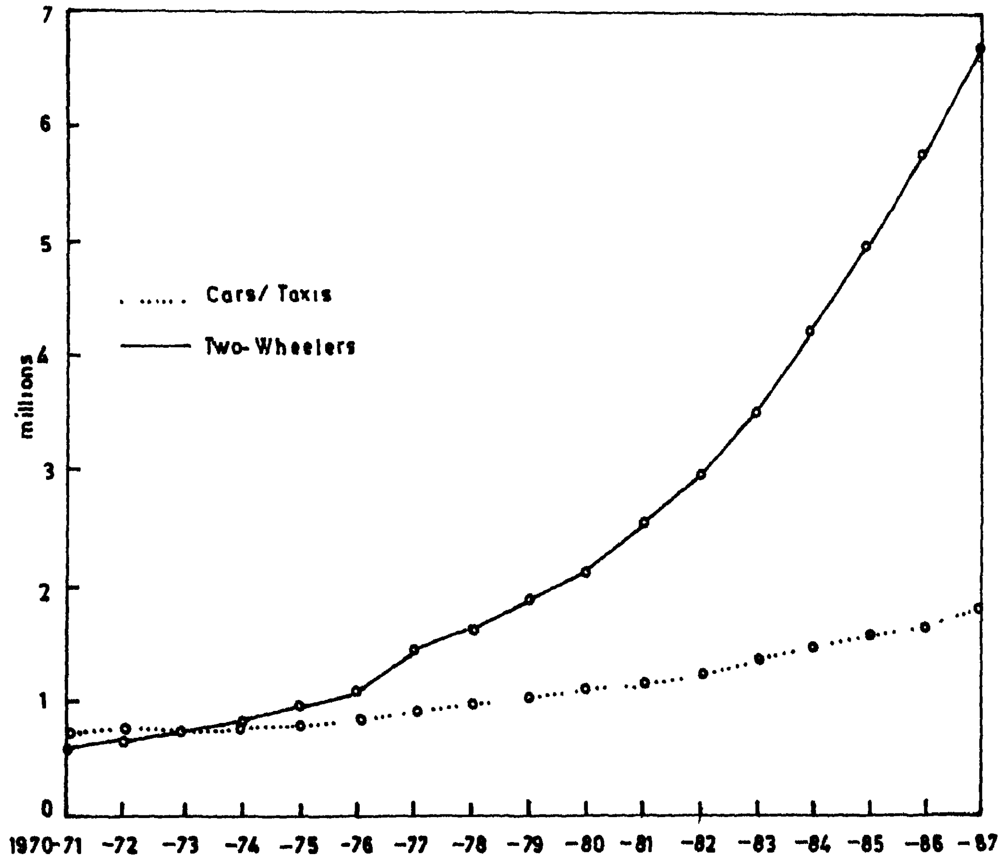


FIG 46: OCCUPANCY RATIO OF BUSES

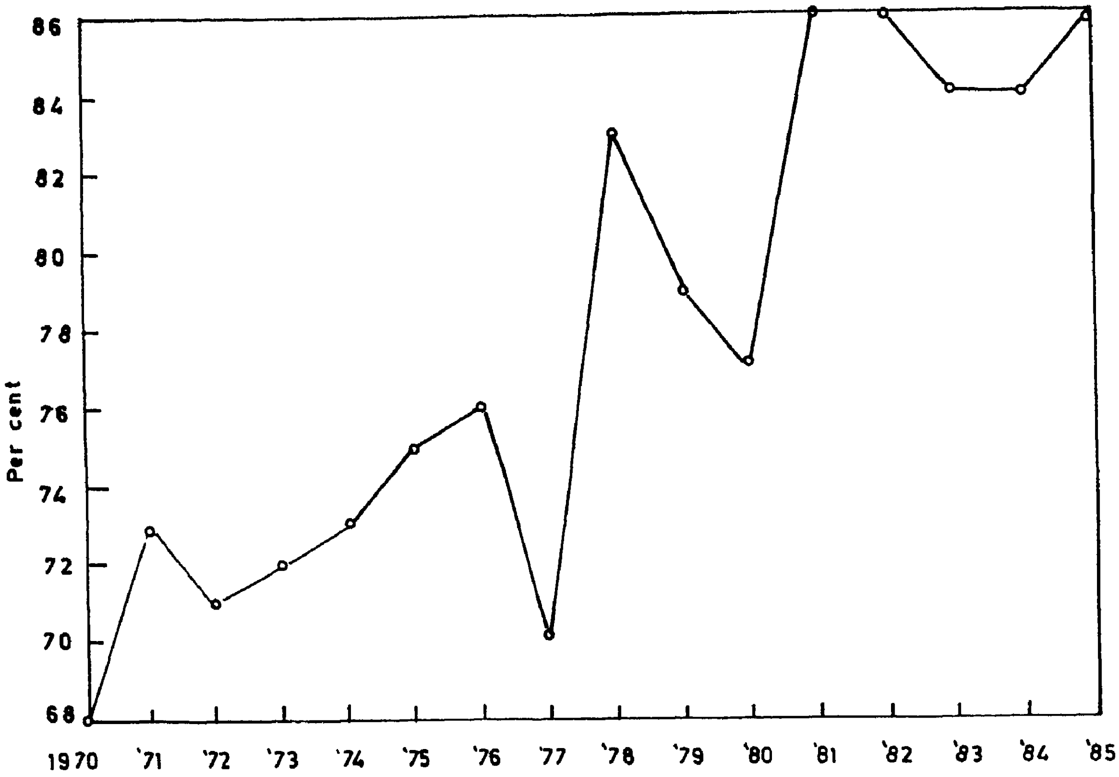


FIG 4.7 AVERAGE LOADING OF TRUCKS

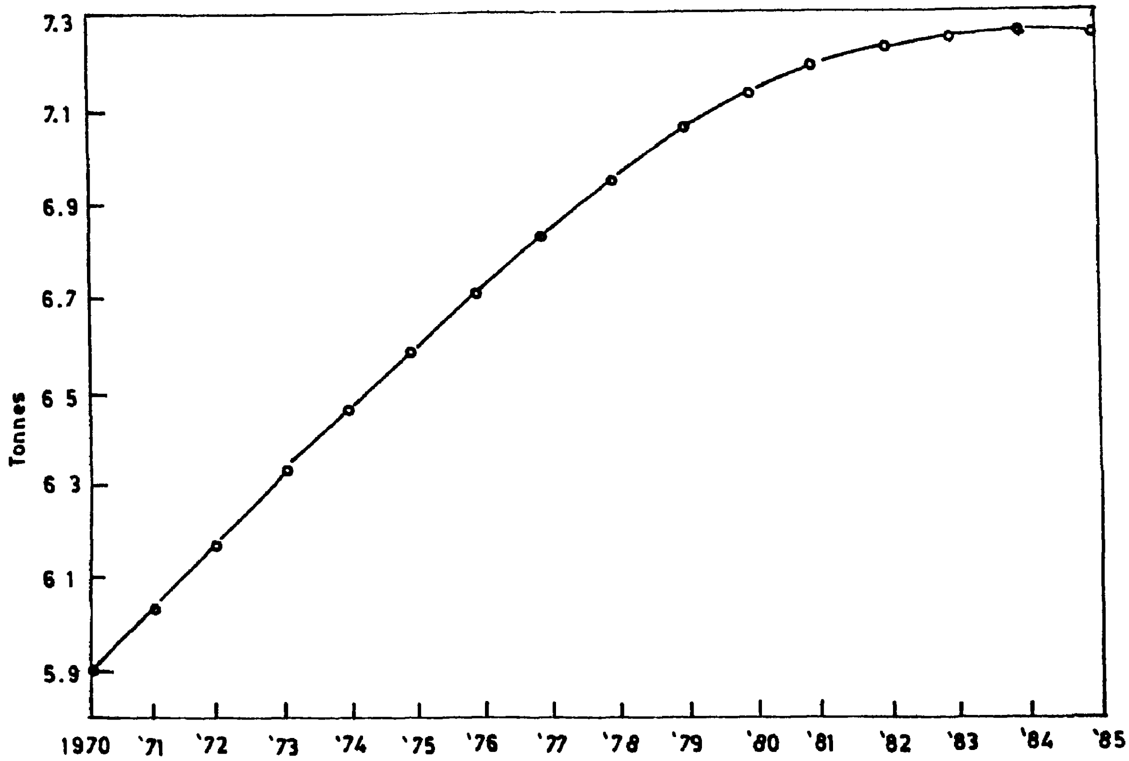


FIG. 4.8 ENERGY INTENSITY IN WATER & AIR TRANSPORT

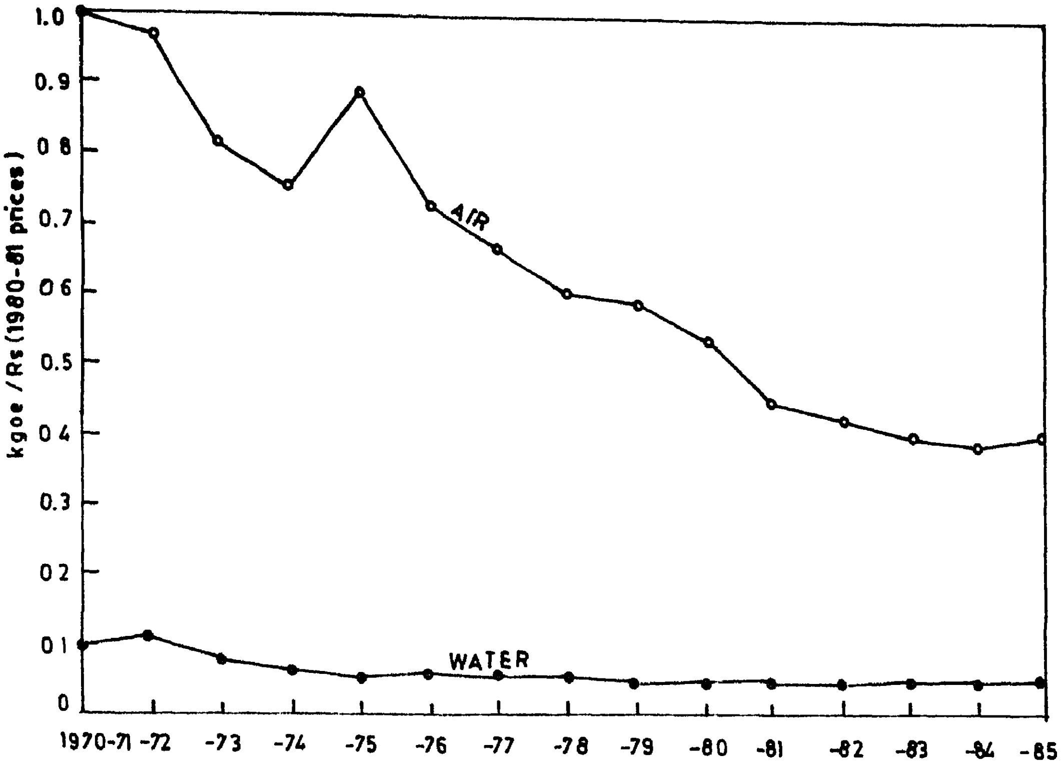
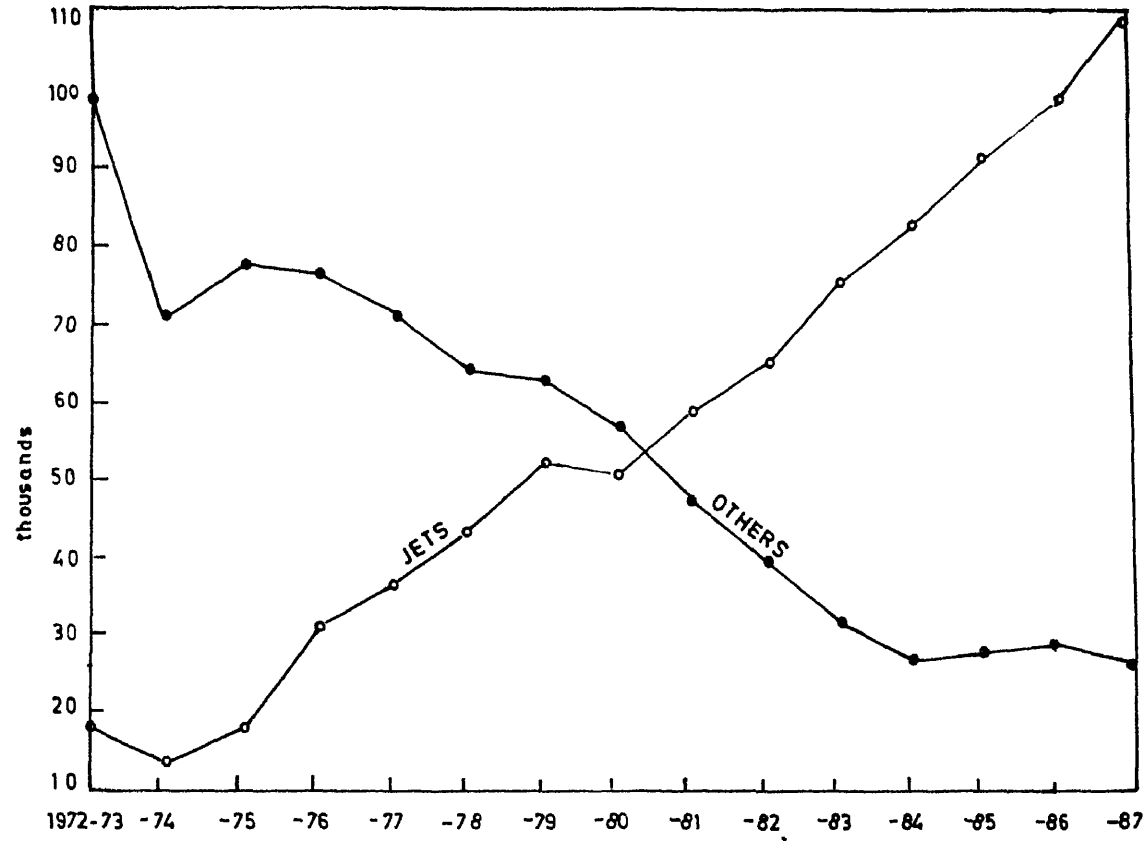


FIG. 49 REVENUE FLYING HOURS OF VARIOUS CRAFT



V. COMMERCIAL/SERVICES/GOVERNMENT SECTOR

5.1 Introduction

Schools, hospitals, private businesses, hotels, restaurants, Government buildings, offices and other energy consuming centres not included in agriculture, industry, transport and residential sectors comprise the commercial/ services sector. Information on value added is usually disaggregated into trade/hotels, banking/insurance, real estate and other services. According to available information, the composition of the sector has changed somewhat since the early 1970s. The share contribution of banking/insurance to the total value added in the sector increased substantially from 8.7% in 1970/71 to 13.6% in 1984/85, while that of real estate and other services declined from 15.1% to 13.3% and from 21.1% to 18.3% during the same fifteen year time period. Trade/hotels continued to account for about 55% of the total gross value added in the sector.

5.2 Energy Uses

A wide variety of energy consuming end-use activities characterize this sector. These include cooking, lighting, space heating, space cooling, refrigeration, pumping and so on.

Readily available energy consumption data are not disaggregated in general, either by end-use or by type of establishment. Only published electricity sales statistics are disaggregated as per water and sewage supply works, street lighting, commercial buildings and miscellaneous. Traditional energy sources (such as wood fuels etc.) may also be used in certain commercial establishments (for instance, road-side tea stalls); but information on this aspect is very sketchy.

For both traditional and commercial energy fuels, it may be best to rely on information gathered through isolated sample surveys.

5.3 Trends of Energy Intensity

The sector however, is not a major energy consumer. Its energy consumption intensity in 1984/85 was 0.714 mtoe/Rs. hundred billion or 7.14 kgoe/thousand rupees (1980/81 prices), as compared to about 60 kgoe/thousand rupees for the industrial sector. In fact, figure 5.1 shows that the average energy intensity as computed above, seems to have reduced gradually since the early 1970s. This overall trend however, has been marked by considerable changes in the average intensity from year to year. For instance, there was a sudden rise in the sector's energy intensity in 1973/74, which was followed by a gradual decline until 1975/76, a marginal rise in 1976/77, a further decline until 1978/79, and then a sharp rise in 1979/80. Since 1979/80, the trend has been that of a general decline in the overall intensity, although the decline rate has varied significantly from year to year -- the maximum being in 1982/83 (figure 5.1).

Although considerable information is required to provide a complete explanation of the year-to-year changes in the average energy intensity of the sector, some reasons may be understood by closely examining the energy consumption pattern of the sector (Table 5.1 and figure 5.2).

It may be observed that both during 1973/74 and 1979/80, when the overall sectoral energy intensity rose rather abruptly (figure 5.1), the combined share of fuel oils and soft-coke/coal in the sector's total energy consumption mix also increased (figure 5.2). During 1973/74, the share of kerosene declined sharply from over 28% to less than 25%. Likewise, in 1979/80, the shares of both kerosene and electricity reduced; from about 28.6% in 1978/79 to 23% in 1979/80 for kerosene, and from 29% to 24.4% for electricity. On the other hand, during the years when the sector's energy intensity registered a reduction, the reverse was observed. For instance, for 1982/83, the combined share of fuel oils and soft-coke reduced substantially from the previous year (42.1% to 31.1%), while the share of kerosene and electricity increased (28.7% to 34.1%, and 28.5% to 34.0%) respectively.

Such a correlation probably indicates that the use of fuel oils and soft-coke/coal is inherently relatively less energy efficient, compared to that of kerosene and electricity.

Table 5.1 : Energy Consumption in Commercial/Services/Govt Sector (mtoe)

	LPG	Fuel Oils	Kerosene	Electricity	Soft-Coke	Total
72/73	0.012	0.583	0.571	0.403	0.453	2.022
73/74	0.013	0.498	0.539	0.445	0.666	2.161
74/75	0.015	0.523	0.473	0.461	0.576	2.048
75/76	0.017	0.475	0.508	0.529	0.520	2.049
76/77	0.016	0.460	0.543	0.580	0.597	2.196
77/78	0.018	0.403	0.594	0.623	0.539	2.177
78/79	0.019	0.519	0.646	0.656	0.422	2.262
79/80	0.022	0.980	0.633	0.672	0.443	2.750
80/81	0.021	0.734	0.691	0.699	0.416	2.561
81/82	0.017	0.705	0.768	0.762	0.420	2.672
82/83	0.018	0.459	0.853	0.850	0.319	2.499
83/84	0.022	0.458	0.903	0.933	0.279	2.595
84/85	0.025	0.463	0.975	0.987	0.305	2.755
85/86	0.035	0.450	1.019	1.033	0.338	2.875
86/87	0.030	0.327	1.085	1.167	0.292	2.901

onversion Factors :

LPG 1 million tonnes = 1.058 mtoe
Fuel Oil 1 million tonnes = 0.956 mtoe
Kerosene 1 million tonnes = 1.009 mtoe
Soft-coke 1 million tonnes = 0.490 mtoe
Electricity 10,000 GWh = 0.844 mtoe

FIG. 5.1: ENERGY INTENSITY IN THE COMMERCIAL SECTOR

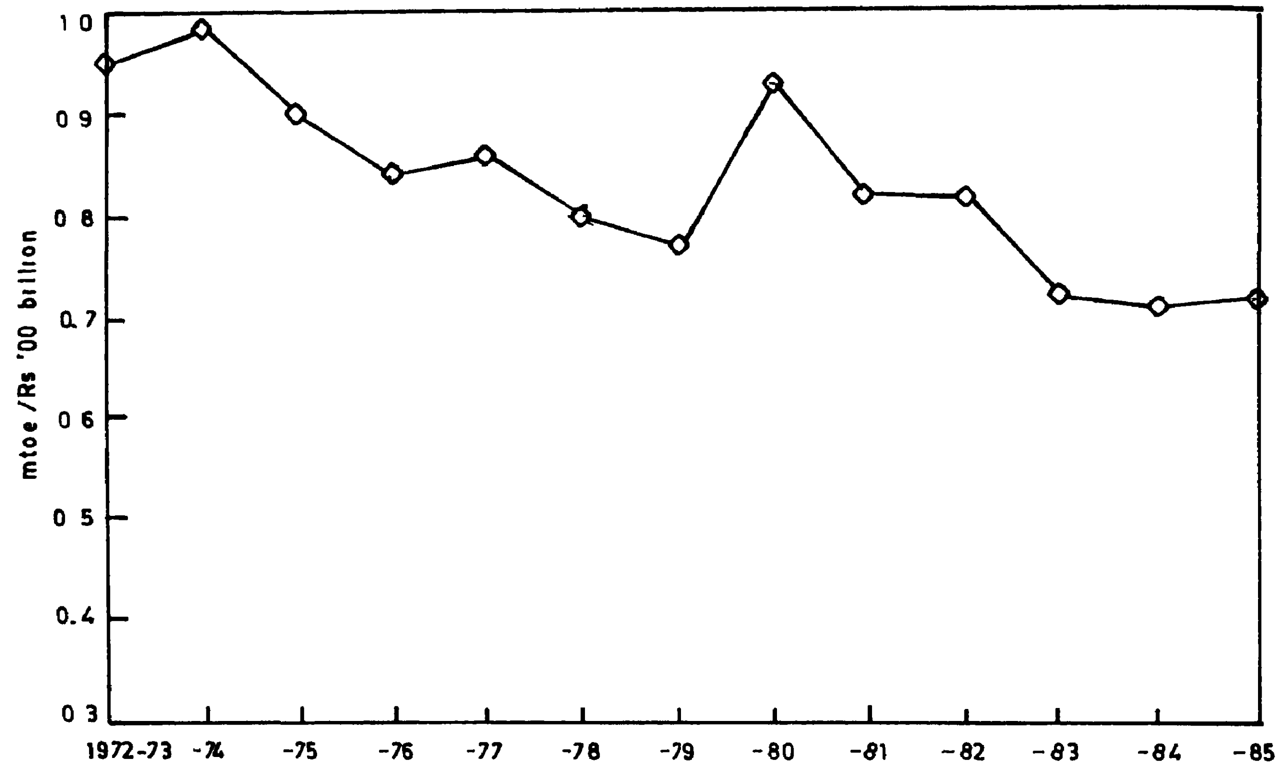
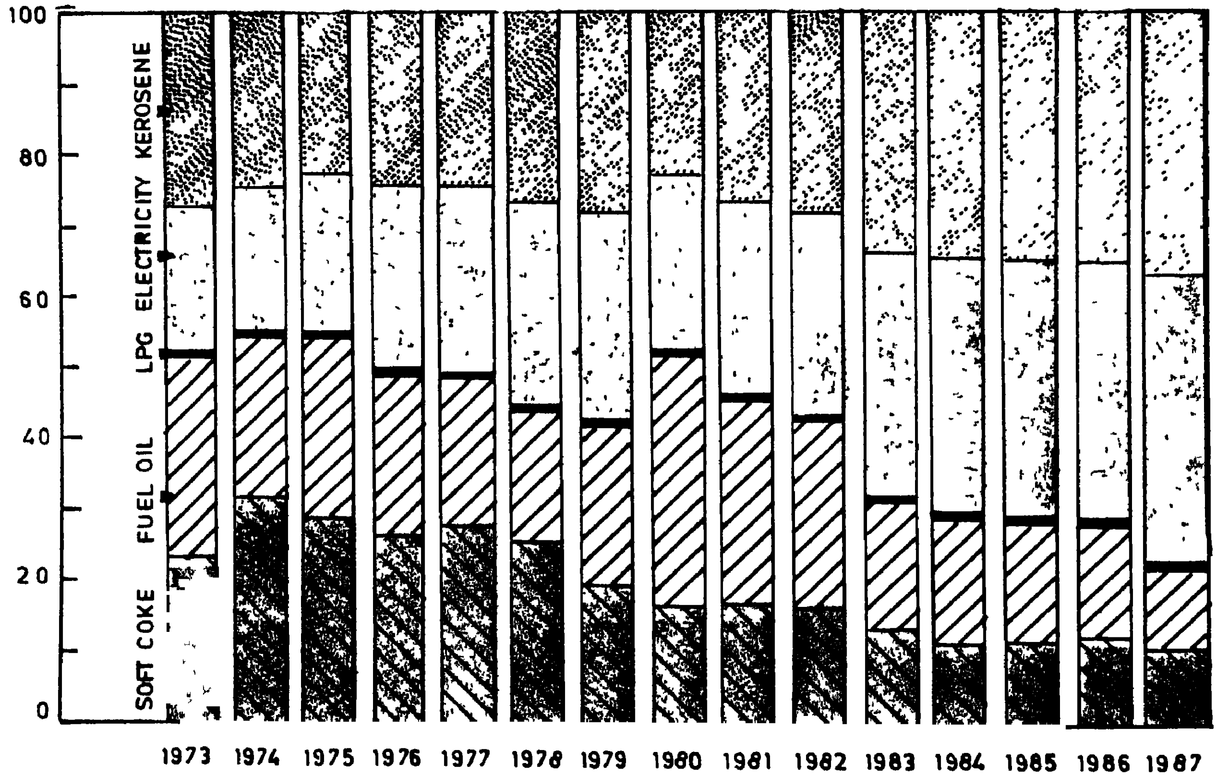


FIG 5.2: ENERGY CONSUMPTION IN THE COMMERCIAL/SERVICES/ GOVERNMENT SECTOR (%)



VI. RESIDENTIAL SECTOR

6.1 Introduction

The residential sector is the largest consumer of energy, accounting for approximately half of the total energy consumption in the country. Using conventional methods, it is rather difficult to attribute or quantify the "value added " contribution of the sector. Therefore, there is no direct way of comparing the energy consumption intensity of the residential sector with other sectors. However, a convenient way of comparing energy use in various households -- or various categories of households -- is to quantify the annual per capita energy consumption levels.

A large fraction of the energy used in households comprises traditional fuels, such as fuelwood, crop residues and animal wastes. Regarding the use of these fuels, only some indicative data, gathered through field surveys, are available. The data presented in survey reports are not based on actual measurements, but are largely "impressions" of the quantity used. The information thus gathered may be considered to be only of a qualitative nature. Available data on the consumption of commercial energy forms are generally more reliable.

6.2 Energy Consumption Mix

Field surveys to date have broadly indicated that the share of commercial fuels in the total household energy consumption mix is higher in urban households than in rural. Furthermore, the share of commercial fuels normally increases with the size of town/city, and in general, is maximum for metropolitan cities. Table 6.1 illustrates these observations.

It may be noted that the data in Table 6.1 relate to 1978/79. Although there have been significant changes in the household energy consumption mix since 1978/79, the general pattern regarding the commercial-traditional fuel mix in rural and urban areas remains essentially unchanged. Some aspects of the changes in the fuel mix are discussed further in subsequent sections.

Another interesting fact observed in Table 6.1 is that the total residential energy consumption per capita is more in rural areas than in urban; and the average for all urban areas is higher than in metropolitan cities like Delhi. This is due largely to the fact that the end-use efficiency associated with commercial energy forms is usually higher than that for traditional fuels -- which means that a certain quantity of a commercial fuel with a certain amount of intrinsic heat value may substitute for a larger heat value of traditional fuels for delivering exactly the same amount of "useful" energy.

Owing to lack of comprehensive information on the efficiency levels of various end-use devices, it is not possible to estimate the useful energy requirements of rural, urban and metropolitan households. However, it may very well be that the average useful energy requirements of households in rural areas is less than that in urban areas, with the maximum being in metropolitan cities. This may be expected, even if only because the average household income level is the least in rural areas and maximum in metropolitan cities.

6.3 The Changing Roles of Traditional and Commercial Fuels

The discussion above probably suggests that the share of traditional fuels reduces with the rise in expenditure/income levels. This is evident in both rural and urban households (figs. 6.1 and 6.2 respectively), although the trend is more noticeable in urban areas. In rural areas, a considerable amount of traditional fuels (wood fuels, crop residues and animal wastes) are obtained at zero financial costs by households of all income categories. The upper income households probably have sufficient cattle or/and land holdings to yield sufficient crop or/and animal wastes. The lower income households obtain the necessary fuels largely by spending time in collecting them.

The relative roles of traditional and commercial fuels however, are reported to have changed with time. This change has occurred for a variety of reasons, including a growing scarcity of certain fuels and increasing availability of others, changes in relative price levels, changes in income/expenditure levels and increasing awareness of the benefits or advantages that may be derived from using certain "superior" fuels.

Estimated changes in the fuel consumption pattern from 1974/75 to 1978/79 are detailed in the TERI Energy Data Directory and Yearbook (1988). Our baseline data are about ten year old (for 1978/79) and do not provide much insight into the present household energy consumption mix by type of fuel.

Available data on the fuel mix in the various expenditure/income categories of households in rural and urban areas indicates a wide range of per-capita use of various fuels. This is due largely to the fact that for end-uses such as cooking, water heating and space heating, a variety of traditional and commercial fuels may be used1). For lighting, either kerosene and electricity may be used. The efficiency with which different fuels may be used for the same end-use may vary -- which again effects the per-capita energy consumption level when measured in kgoe or other direct heat unit terms. Electricity alone may be used for other appliances like refrigerators, television sets, fans etc.

While it may be expected that all households will try to emulate the energy consumption pattern of the high expenditure/income category households, there is no concrete

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1) Of course, a different stock of appliances may be necessary for using different fuels for the same end-use.

evidence to support this hypothesis. It is relatively clear however, that various electrical devices/appliances/gadgets that are introduced in the market, are to begin with, purchased largely by the upper income households. And the increase in the production and sales of certain appliances in recent years (Table 6.2) suggests that they have been increasingly purchased, at-least by households of the upper-middle to lower-middle income groups as well2). The increasing use and availability of electrical appliances, suggests that the per-capita electricity (and therefore energy) consumption levels in the residential sector are increasing.

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2) It may be noted that data on sales of various appliances are not readily available. Only production data are available, which may be considered as a surrogate for sales data. It is important to note however, that a certain fraction of the population of appliances may in fact be used in other sectors (particularly the commercial/services/Government sector).

Table 6.1: Per-capita Energy Consumption

	Rural Households	All Urban Households	Households in Delhi
Traditional Energy			
- kgoe	104.9	50.1	6.1
- %	95.0	62.8	9.0
Commercial Energy			
- kgoe	5.6	29.7	61.8
- %	5.0	37.2	91.0
Total Energy			
- kgoe	100.4	79.8	67.9
- %	100.0	100.0	100.0

Source: National Council for Applied Economic Research (NCAER), Domestic Fuel Survey with Special Reference to Kerosene (1978/79), New Delhi, 1981.

Table 6.2: Production of Selected Household Appliances ('000)

	1970	1980	1985	1986
Television Sets	5.1	86.8	2480*	3000*
Portable Room Air-Conditioners	17.0	26.2	31.0	39.5
Refrigerators	65.4	278.0	677.6**	591.4**

* Production of large, medium and small scale industrial units.

** Data refer to financial year.

Source: Centre for Monitoring Indian Economy, Production and Capacity Utilization in 600 Industries, October 1987.

FIG. 6.1: CONSUMPTION OF TRADITIONAL AND COMMERCIAL FUELS IN RURAL HOUSEHOLDS (%)

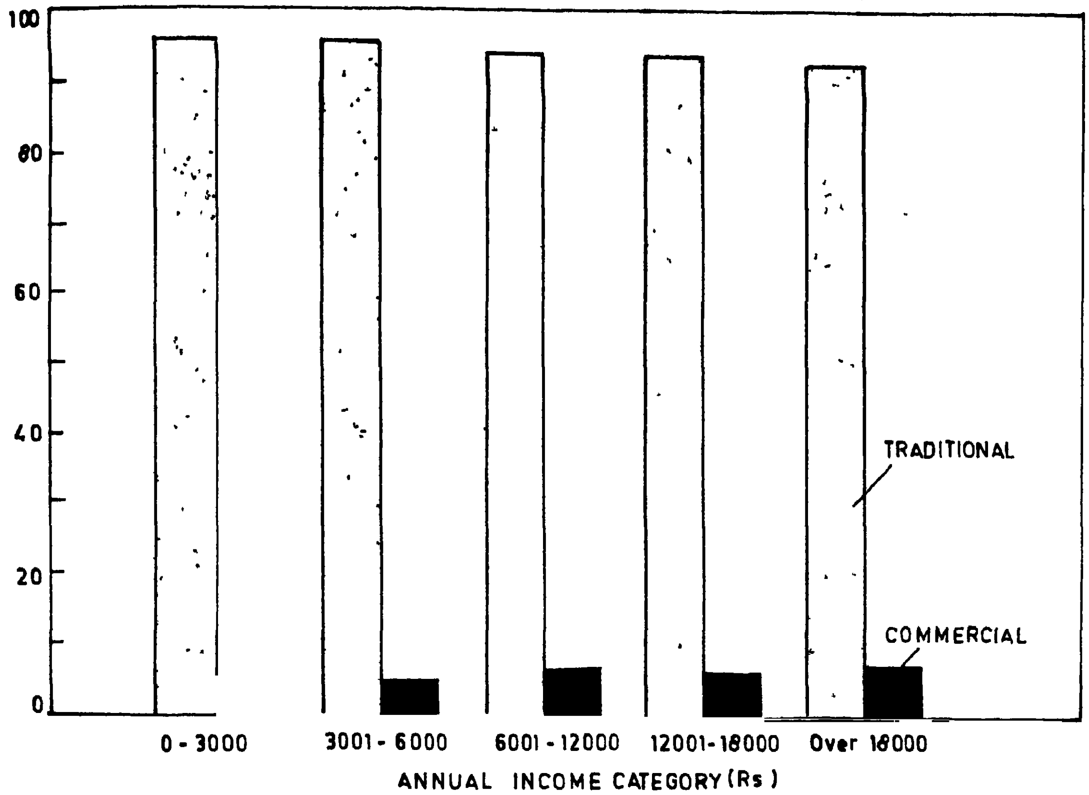
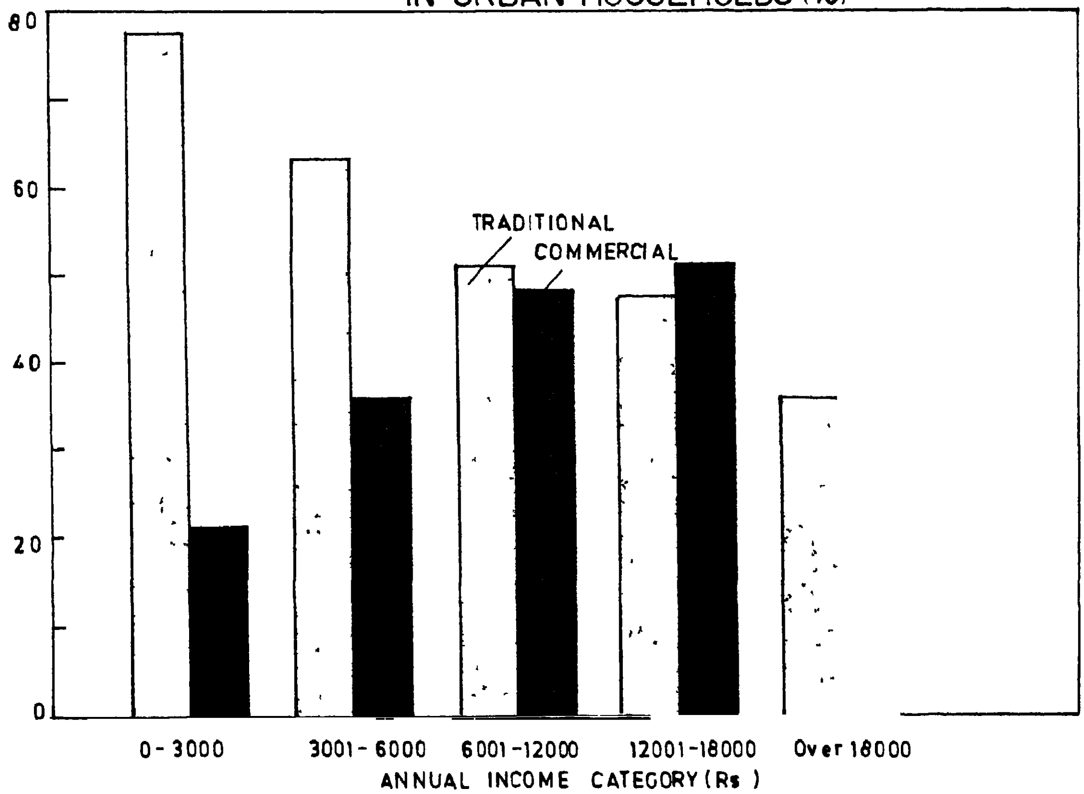


FIG 6 2: CONSUMPTION OF TRADITIONAL AND COMMERCIAL FUELS IN URBAN HOUSEHOLDS (%)



VII. SUMMARY

The analysis in previous sections has shown that the overall energy intensity in the Indian economy has reduced considerably since the early 1970s -- although not necessarily uniformly across the various energy consuming sectors and sub-sectors. The overall reduction has been due largely to changes in the structural characteristics of the economy (as relatively less energy intensive activities gained prominence compared to the more intensive ones) and changes in the energy consumption mix (as relatively superior fuels come to substitute traditional energy sources), and only marginally due to a genuine success in implementing energy conservation measures in industrial, agricultural, transport, residential and other energy consuming sectors. By and large, the energy consumption intensity of a particular process or end-use in India remains much higher than in developed countries. Further reduction in energy intensity -- and a significant one at that -- is therefore clearly possible. -

The need for using fuel efficiently was recognized by the Government of India in the early 1960s, much before the first oil shock. Since then, from time to time, various committees and expert groups have been constituted to examine specific aspects of energy supply and demand, and recommend suitable policy options. The Ministry of Energy has been primarily responsible for evaluating their recommendations.

The recommendations which have been accepted by Government have been adopted through legislative acts and proclamations.

The Ministry of Energy, primarily through the Department of Power, has been monitoring the impact of incentives related to industry. Occassionally, studies have been conducted by various national agencies and institutes to assess the benefits derived from incentives offered to various industries. The Departments of Coal, Petroleum, Industrial Development and Non-Conventional Energy Sources, the Ministry of Finance, and the Planning Commission have also been entrusted with monitoring of energy conservation in industry. In early 1987, the Advisor, Energy Conservation was appointed by the Government to speed up conservation efforts not only in industry but also in other energy sectors.

As the industrial sector in India is the largest consumer of commercial energy, and at fairly low efficiencies, policies to promote energy conservation and rationalization are important. Although the complex nature of indstry in India poses many challenges which have to be tackled by the policy makers, the industrial sector is much better organized than other sectors -- and policy measures to rationalize energy use may in general, be expected to have a better chance to have the desired impact. Policy instruments adopted by the Government of India so far, for the promotion of efficient use of energy in the industrial sector have been mainly in two areas -- fiscal and economic measures, and liberalization of import of certain energy equipment.

It is understood that energy savings of as much as 15 to 20% are possible in certain types of industry with marginal additional investments, better house-keeping and better capacity utilization. Specific measures that are being or can be adopted by the iron and steel and cement industries, are discussed in chapter 3.

The discussion on energy use in the agriculture sector (chapter 2) reveals the difficulties experienced in estimating the energy requirements per unit yield of various crops. Notwithstanding the problems associated with estimating energy intensities of the sector, available data (presented in the TERI Energy Data Directory and Yearbook 1988) clearly show that commercial energy intensity of the sector has increased substantially during the past decade or so. It may therefore be worthwhile to review farm mechanization strategies, not only from the point of view of energy consumption, but also with due regard to incremental yield levels expected from mechanization.

Nevertheless, as pointed out by the Inter-Ministerial Working Group on Utilization and Conservation of Energy, energy savings in diesel and electric pumpsets of as much as 30% are possible if due attention is given to the following problems which were identified : (i) proper sized pumps are not usually installed, and the water lift head range in which the pump operates efficiently is often very different from actual operating conditions; (ii) there is no proper maintenance; and (iii) there are other problems, such as the delivery pipe may be either too short or too long, the suction pipe may have an air leak, certain pipe fittings may be used even when they are not required, footvalves and strainers may have high resistance which increases friction losses, and so forth.

As far as the transport sector is concerned, it is evident from the discussion in chapter 4, that energy intensity of all transport sub-sectors (rail, road, water, air) has reduced substantially since the early 1970s. However, it is relatively clear that except for the road transport sector in recent years, this intensity reduction is due largely to structural changes in the composition of each of the sub-sectors, and not because of improvements in the energy efficiency levels of the particular modes. Significant improvements in the management of rail and road transport modes (the two most important ones in the country) are possible. In particular, further reductions in intensity of road transport, which is the major consumer of liquid fuels in India (accounting for about 32% of total petroleum products sales in 1986/87) seem imperative. Steps taken in this direction during the past few years should be supplemented by upgrading road surfaces and widening roads. And a coherent Government policy of promoting expansion of the railways will also help to reduce the overall energy intensity of the sector.

As for the residential and commercial/services/Government sectors, the potential for energy conservation is substantial. For instance, better building design and architecture can reduce the need (and energy use) for space heating and cooling. A switch from incandescent to flourescent lighting can help to reduce electricity consumption for lighting. Improved cookstoves (using fuelwood or kerosene or LPG) can help to reduce cooking energy needs.

In general, the various processes in the energy cycle where the potential for energy conservation exists and is substantial, are known. What is lacking is an appropriate policy directive which provides for a regulatory mechanism, technology packages, a system of incentives and penalties, and a programme for enhancing the awareness of the energy users on the impelling need for energy conservation.